THE EOCENE FALKLAND FOSSIL FLORA,

OKANAGAN HIGHLANDS, BRITISH COLUMBIA:

PALEOCLIMATE AND PLANT COMMUNITY

DYNAMICS DURING THE

EARLY EOCENE CLIMATIC OPTIMUM

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ABSTRACT

The fossil flora and depositional setting of the early Eocene Falkland site in the southern interior of British Columbia, Canada is reported here in detail for the first time. Falkland is part of a series of fossil localities that occur in a region known as the Okanagan Highlands. These sites represent relatively cool upland environments in the greenhouse world of the early Eocene. Macrofossil collections were obtained from Falkland using an unbiased census approach with systematic sampling through three informal units in the exposed outcrop. A stratigraphic log reveals a lacustrine sequence dominated by finely laminated mudstone or shale with periodic influx of coarser material, punctuated by thin volcanic ash layers. Paleoelevation of the site is estimated based on paleobotanical evidence to have been similar to or slightly higher than modern levels (≥1.3 km) during the early Eocene.

Paleoclimate is assessed using both physiognomic and floristic approaches as applied to the Falkland flora. Physiognomic approaches correlate aspects of leaf morphology with climate, while floristic approaches use the tolerances of modern nearest living relatives to infer a climate envelope for the fossil flora. Overall, the different methods give broadly consistent results, with an identifiable zone of overlap in the estimates for mean annual temperature at ~10.5°C, cold month mean temperature at 2.3–6.3°C, warm month mean temperature at 20.2–23.7°C, and a minimum mean annual precipitation of 82–120 cm/yr. Assessment of paleoclimate for the three individual units indicates a cooling trend over time, consistent with a radiometric date of 50.61±0.16 Ma that places the site in the waning phase of the Early Eocene Climatic Optimum (EECO).

The stomatal frequency of fossil *Ginkgo adiantoides* from Falkland is used to estimate paleoatmospheric carbon dioxide (pCO_2). Results from Falkland indicate that pCO_2 was significantly higher than modern (>2x) in the early Eocene, although the upper limit of the estimate is unconstrained due to limitations with modern calibration datasets. Analysis of specimens from the three units indicates that climate and pCO_2 were coupled during the EECO. Examination of modern *Ginkgo biloba* leaves suggests that stomatal density is more likely to be accurately measured than stomatal index. In addition, there is a significant difference between stomatal frequencies of long- and short-shoot leaves, suggesting that this factor needs to be taken into account in modern calibration datasets.

The Falkland flora was described in two phases. In the first phase, specimens were assigned to morphotypes, informal categories that ideally correspond to species-level organization. In total, 1561 specimens were assigned to 138 morphotypes encompassing foliage and reproductive structures. The taxonomic literature was then investigated and morphotypes were assigned to formal taxa wherever possible. Gymnosperms are dominated by taxa in Cupressaceae, Pinaceae, and Ginkgoaceae, and there is a diverse angiosperm flora particularly rich in taxa belonging to Rosaceae, Betulaceae, and Sapindaceae. Rarefaction analysis shows Falkland as having diversity comparable to that of the hyper-diverse Laguna del Hunco site in Argentina. These data are consistent with an emerging understanding of high diversity in early Eocene forest communities associated with mild but equable climates. The Falkland flora retains a foundation of common taxa through all three units, including *Metasequoia*, *Ginkgo*, and *Alnus*; however, there is a distinct plant community in the upper unit as angiosperms become more abundant and the assemblage more diverse. Patterns in plant diversity are assessed within a context of changing climate and an active disturbance regime at the Falkland site.

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LIST OF ABBREVIATIONS

BC:	British Columbia
CA:	Coexistence Approach
CLAMP:	Climate Leaf Analysis Multivariate Program
CMMT:	Cold Month Mean Temperature
EECO:	Early Eocene Climatic Optimum
FQ:	Fossil Quality
LAA:	Leaf Area Analysis
LMA:	Leaf Margin Analysis
MAP:	Mean Annual Precipitation
MAT:	Mean Annual Temperature
NLR:	Nearest Living Relative
NMDS:	Non-Metric Multidimensional Scaling
PETM:	Paleocene-Eocene Thermal Maximum
SD:	Stomatal Density
SI:	Stomatal Index
SR:	Stomatal Ratio
WA:	Washington State
WMMT:	Warm Month Mean Temperature

1. INTRODUCTION

Shellito and Sloan (2006) described the Eocene world as a "lost paradise," when tropical vegetation extended well north of current ranges, and the poles were ice-free. While the pursuit of knowledge regarding the diversity and evolution of terrestrial plant ecosystems remains a key goal of paleobotany, study of the plant fossil record has taken on an added dimension of practical importance in providing proxy data for the reconstruction of paleoclimate that can be used to test and refine global climate models (Wing and Greenwood, 1993; Sloan, 1994; Greenwood and Wing, 1995; Wilf, 2000; Sewall et al., 2000; Greenwood, 2007; Greenwood et al., 2010; Smith et al., 2010). Recent modeling efforts have moved towards regional climate models that provide a higher-resolution testing ground for the match between models and proxy data, and depend on accurate characterization of vegetation and land cover type, as well as high-density, accurate proxy datasets (Thrasher and Sloan, 2009, 2010). As anthropogenic global warming pushes ecological systems towards limits not encountered within the history of instrumental measurement, the best guide to developing realistic models of global climate change and biotic response is found in the fossil record (Royer, 2008).

Plant fossils yield information on terrestrial paleoclimate and atmospheric composition that complements geochemical proxies, and provide an indication of what the world can look like under very different global climate conditions. Since the current public policy focus on global climate issues stems from concern over anthropogenic warming, there is particular interest in studying periods of Earth history that represent "greenhouse" climates. One such key period is the early Eocene. The interval of peak warmth during the Cenozoic occurred ~53 to 50 Ma at the Early Eocene Climatic Optimum (EECO; Zachos et al., 2001, 2008). Unlike short-term aberrations in climate, such as the Paleocene-Eocene Thermal Maximum (PETM, ca. 55 Ma), the EECO was the culmination of a longer-term warming trend that began in the mid-Paleocene (Zachos et al., 2001). While other greenhouse intervals occurred further back in deep time, the early Eocene marked the appearance of many modern plant and animal families, and Northern Hemisphere continental configurations were not dramatically different from the present day (Wing et al., 2000). Therefore, this interval offers one of the best opportunities to study biotic response to global climate change in a much warmer world (Wing et al., 2000).

A series of fossil localities in British Columbia, Canada, and Washington, USA, span the EECO and have been found to yield diverse and well-preserved plant and insect fossils (Archibald and Greenwood, 2005; DeVore et al., 2005). This suite of coeval sites known as the Okanagan Highlands offers significant opportunities to address questions of climate change and biotic response in the early Eocene (Greenwood et al., 2005; Smith et al., 2009; DeVore and Pigg, 2010). Some sites, such as Republic in Washington and McAbee in British Columbia have been the subject of extensive collecting efforts, and provide a substantial body of material and analysis – both taxonomic and paleoecological in nature – that supports work at newly discovered or under-reported localities (DeVore and Pigg, 2010). One such locality is near the town of Falkland in south-central British Columbia (50.516°N, 119.628°W). This site was briefly mentioned as a source of insect fossils by Rice (1959) and Wilson (1977) but without details of the site locality. The first significant mention of the site was in a survey of Okanagan Highlands fossil localities published as a special volume of the *Canadian Journal of Earth Sciences* (Greenwood et al., 2005; Moss et al., 2005). The Falkland site was the primary field location for the present study, and material from the site was used to answer questions relating to plant community dynamics and paleoclimate in the early Eocene, with details of the site locality described for the first time in the papers that comprise this dissertation.

Fieldwork for this project occurred over three field seasons from 2006 to 2008. Collecting efforts were carried out using an unbiased, census sample methodology (Wilf et al., 2003, 2005) in order to permit the application of quantitative research methods, and to facilitate a high-resolution study of within-site trends in paleoclimate and plant community composition and diversity. This approach also allowed meaningful comparisons to be made with a small number of other early Eocene sites in North and South America than have been collected using a similar approach (e.g. Wilf et al., 2003, 2005). The goals of this project were threefold:

1. Describe the Falkland locality in terms of depositional setting and fossil flora
2. Use paleobotanical evidence to reconstruct the paleoclimate of the site
3. Examine plant community dynamics operating in the early Eocene Okanagan Highlands, as reflected in the fossil record

The following chapters were prepared as papers intended for publication; therefore, each can be treated as a stand-alone document and has its own introduction and review of relevant literature.

Chapter 2, "Depositional setting, fossil flora and paleoenvironment of the early Eocene Falkland site, Okanagan Highlands, British Columbia," is the foundational paper of this project in that it provides the first detailed report of the Falkland fossil locality in the literature (published as Smith et al., 2009). The emphasis in this paper is on describing the depositional setting and stratigraphic context of the site, as this informs all subsequent investigations of the flora and paleoclimate. A new stratigraphic log of the exposed outcrop provides geological evidence for characterizing the site as a lacustrine deposit in a low-energy environment punctuated by periodic disturbance in the form of volcanic eruptions, and at least one significant shift in lake levels. The outcrop was divided into three informal units on the basis of laterally continuous volcanic ash layers and changes in site lithology.

In addition, paleobotanical evidence is brought to bear on the question of the paleoelevation of the site. Two approaches to estimating paleoelevation are utilized: one based on the mean annual temperature (MAT) of the site as compared to approximately coeval sites at sea-level in combination with terrestrial lapse rates, and the second based on differences in enthalpy between sea level and upland sites. Both approaches suggest that the site was at a similar or slightly higher elevation in the early Eocene compared to the modern day ($\geq$ 1.3 km), and support the characterization of the site as an upland environment within the early Eocene landscape. In addition to providing geological and paleoenvironmental context, this paper gives an initial qualitative overview of the fossil flora at the site along with preliminary estimates of paleoclimate using leaf physiognomy (correlating aspects of leaf morphology with climate), topics that will be taken up in greater detail in subsequent chapters.

Building on the foundational analysis and site description in the previous chapter, Chapter 3, "Estimating paleoatmospheric $p\mathrm{CO}_2$ during the Early Eocene Climatic Optimum from stomatal frequency of *Ginkgo*, Okanagan Highlands, British Columbia, Canada," uses fossil material from the Falkland site to tackle a question of particular relevance to current interest in understanding the links between atmospheric carbon dioxide ($p\mathrm{CO}_2$) and climate. Estimates of $p\mathrm{CO}_2$ for the early Paleogene vary from near modern-day levels to an order of magnitude greater, based on a variety of proxy measures (Royer, 2006). The stomatal frequency of land plants is one proxy that can be used to estimate paleo-$p\mathrm{CO}_2$. Stomata are the controlled pores through which plants regulate gas exchange with the atmosphere, and observational and experimental studies have shown that frequency of stomata on the leaf surface is inversely correlated with $p\mathrm{CO}_2$

(Royer, 2001). Earlier studies using the stomatal frequency of early Paleogene fossil *Ginkgo* suggested that pCO_2 levels were similar to the present day (Royer et al., 2001). This would indicate that climate and pCO_2 were decoupled during this globally warm period, at odds with evidence from other proxies that indicate significantly elevated pCO_2. This study (published as Smith et al., 2010) provides supporting evidence for proxies that suggest pCO_2 >2x modern levels. Additionally, there is a correlation between declining temperature and declining levels of pCO_2 over time at the site, as indicated by stomatal frequency, suggesting that climate and pCO_2 were coupled during the EECO.

This paper also includes a critical assessment of the stomatal frequency method using a dataset of modern *Ginkgo biloba* leaves. Importantly, findings suggest that stomatal density, rather than stomatal index, may be the preferred measure of stomatal frequency in the case of *Ginkgo*. Although stomatal index is generally regarded as the more robust measure, since it is less affected by environmental factors (Royer, 2001), this theoretical advantage is likely lost in application, due to the difficulty in discerning the boundaries of epidermal cells in *Ginkgo* cuticle required to calculate the stomatal index. In addition, this paper argues that the utility of the stomatal frequency proxy is limited in cases of elevated pCO_2 due to the nature of the available modern calibration sets, and the demonstrated ceiling response of *Ginkgo* stomatal frequency to elevated pCO_2 in experimental settings.

Chapter 4, "Early Eocene plant diversity and dynamics in the Falkland flora, Okanagan Highlands, British Columbia, Canada," provides a detailed description of the fossil flora of the Falkland site, and examines plant community dynamics in the fossil record. The description of the Falkland flora proceeded through two major phases, the first being the separation of the fossil specimens into morphotypes, informal taxonomic categories that ideally segregate fossil specimens at the species level, but without the necessity of assignment to formal taxa. The second phase of this process involved a review of the taxonomic literature relevant to the Falkland locality in order to assign morphotypes to recognized species wherever possible. This paper includes a floral list for the Falkland site, and an appendix comprised of the leaf architecture database records for individual morphotypes.

Chapter 4 also examines trends over time in measures of plant diversity and plant community composition through an analysis of specimens from the three units established within the site. This analysis found that diversity increased through the section, with highest diversity in the upper (youngest) unit. In addition, a distinct plant community exists in this upper unit, as demonstrated by a multivariate ordination of species abundance data. The diversity of the Falkland site was also compared to diversity at other early Eocene fossil localities through the use of rarefaction analysis. This analysis shows that, for sample size, Falkland is as diverse as the hyper-diverse early Eocene Laguna del Hunco site in Argentina. These results support recent work that demonstrates tropical-style diversity in cool but equable early Eocene Okanagan Highlands localities, based largely on the fossil insect record (Archibald et al., 2010). Patterns in plant diversity are assessed within a context of changing climate, declining pCO_2 and an active disturbance regime, as established in the previous two chapters.

Chapter 5, "Paleoclimate reconstruction of the early Eocene Falkland locality, Okanagan Highlands, Canada – a comparison of physiognomic and floristic approaches," takes a detailed look at the various methods available for reconstructing paleoclimate from paleobotanical evidence as applied to the Falkland site. Although preliminary paleoclimate estimates were provided in the earlier papers as necessary context to the description of the site and fossil flora, this paper presents a comprehensive analysis of paleoclimate for the site as a whole, as well as for the three individual units, using both floristic and physiognomic methods as applied to the final fossil dataset. The application of floristic approaches to paleoclimate reconstruction requires that the flora be described and identified as fully as possible in order to identify potential nearest living relatives in the modern flora, a process completed in the previous paper (Chapter 4).

Physiognomic methods of leaf margin analysis, leaf area analysis, and the climate leaf analysis multivariate program (CLAMP) were applied to the Falkland site as a whole, and to the three individual units in order to track change over time. In addition, the coexistence approach, which uses the tolerances of nearest living relatives in the modern flora to identify the climate envelope for the fossil flora, was applied to the site. Combining physiognomic and floristic approaches to paleoclimate reconstruction has been identified as a key area for future research, in order to assess consistency of results from a range of methods that rely on different aspects of the fossil flora (DeVore and Pigg, 2010). The various methods were applied with a critical view to understanding their strengths and weaknesses, and to assessing their validity within the context of the Okanagan Highlands fossil floras. The different methods produce broadly consistent results, with zones of overlap identifiable for each of the major climate parameters considered, thereby increasing confidence in the paleoclimate reconstruction.

The major contribution of this study is in providing an integrated approach to the description and assessment of the Falkland flora from a paleoecological perspective. The implementation of census sampling, and the richness and abundance of the fossil specimens permitted the application of quantitative approaches to understanding trends in climate and plant community composition and diversity at the site. Therefore, rather than a static "snap-shot" of a fossil locality, the results of this study present a dynamic plant community situated in a changing landscape shaped by processes of disturbance and climate change. The Falkland flora has previously not been reported in any detail, and so the papers that comprise this dissertation bring this site into the bourgeoning literature on the Okanagan Highlands. These diverse early Eocene floras mark the establishment of many plant families that are important in modern temperate floras of North America, and demonstrate the importance of cool microclimate niches in a globally warm world.

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2. Depositional setting, fossil flora and paleoenvironment of the Early Eocene Falkland site, Okanagan Highlands, British Columbia[1]

Abstract: The fossil flora and depositional setting of the Early Eocene Falkland site in the southern interior of British Columbia, Canada is reported in detail for the first time, using a census sampling approach. The Falkland site is part of the series of Okanagan Highlands fossil localities in British Columbia and Washington State which represent relatively cool upland environments within the context of the greenhouse world of the Early Eocene, providing microthermal (MAT <13°C) climatic conditions for the establishment of cool-adapted plants geographically adjacent to sub-tropical elements from lowland floras. Plant community composition of the Falkland flora is most similar to the Republic (WA) and McAbee (BC) floras based on high Sørenson similarity coefficients, together forming a southern cluster of Okanagan Highlands sites. The site is a lacustrine deposit that formed in a volcanically active landscape. Paleoclimate reconstructions based on leaf physiognomy characterize the site as microthermal (MAT 8.9±2.0°C by leaf margin analysis or 11.9±2.0°C by CLAMP), mesic (MAP 114 cm +49 -35 cm) and equable (CMMT 3.0±2.0°C). Paleoelevation of the site is estimated to be similar to or slightly higher than modern levels (>1.3 km) during the Early Eocene. The Falkland locality adds new data to the temporal, latitudinal, and altitudinal gradients of the Okanagan Highlands series, reflecting the regional landscape of northwestern North America during the warmest period of the Cenozoic.

2.1 INTRODUCTION

The Early Eocene was the warmest interval of the Cenozoic, reaching peak warmth at the Early Eocene Climatic Optimum (EECO) ca. 53–50 Ma (Zachos et al. 2001, 2008). There is currently considerable interest in warm periods in Earth history, particularly in the Cenozoic, as potential analogs for understanding the dynamics of future climate change scenarios (Royer 2008; Zachos et al. 2008). Paleobotanical information can provide estimates of various environmental parameters that can be used to refine climate models in combination with other proxy data (Royer 2008). The Early Eocene Falkland fossil locality in the southern interior of

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British Columbia, Canada is part of a series of correlative sites known as the Okanagan Highlands (Fig. 2.1) that span the EECO (Archibald and Greenwood 2005), and is reported in detail here for the first time.

The richness of the Falkland compression fossil flora in terms of abundance and preservation of specimens rivals the better-known Republic (WA) and McAbee (BC) sites, and is preserved *in situ* with interbedded volcanic ash, providing for stratigraphic analysis and radiometric dating. Collection using a census approach has allowed for identification of fine scale trends in plant community composition and for paleoclimate reconstruction. This study represents the first application of the census sampling approach to a Canadian fossil flora, and provides opportunities for future comparative work with other Eocene sites in North and South America where this approach has been implemented (see Wilf et al. 2003, 2005; Iglesias et al. 2007). The purpose of this paper is to document the geological setting and depositional environment of the Falkland site, and to provide an overview of the fossil flora and paleoclimate. Presented also are paleobotanical estimates of paleoelevation, contributing to prior work on the paleoelevation of western North American macrofloras (Wolfe et al. 1998, 2000). These data will contribute to our understanding of the evolution of the interior British Columbia landscape (Mathews 1991; Tribe 2005; Thompson et al. 2006).

Paleoprecipitation has proven especially difficult to resolve for the Eocene, with wide disparities between climate models and proxy data (Greenwood et al. 2010). Here, we contribute to this debate by applying leaf-area analysis to the Falkland flora to obtain estimates of paleoprecipitation. Previous precipitation estimates by Greenwood et al. (2005) for Okanagan Highlands floras used bioclimatic analysis (a floristic as opposed to physiognomic approach) and other workers have relied on the Climate Leaf Analysis Multivariate Program or 'CLAMP' (e.g., Wolfe and Wehr 1991; Mustoe and Gannaway 1997; Wolfe et al. 1998; Dillhoff et al. 2005), which provides estimates of growing season precipitation, but not mean annual precipitation (MAP).

The Okanagan Highlands fossil localities represent mid-latitude, relatively cool upland environments within the greenhouse world of the Early Eocene geographically adjacent to sub-tropical lowland floras (Wolfe and Wehr 1987, 1991; Wehr 1995; Wolfe et al. 2000; DeVore and Pigg 2007; Greenwood et al. 2005). Systematic analyses of macrofloras from across North America, and particularly for several sites in the Okanagan Highlands, suggest a number of plant families that contribute significantly to modern temperate floras in the northern hemisphere, such as Rosaceae and Betulaceae, underwent rapid diversification in the early to Middle Eocene (DeVore et al. 2005; DeVore and Pigg 2007). These upland sites thus played a crucial role in the evolving landscape mosaic of the Cordilleran region, and in the development of temperate forest ecosystems in North America (Johnson 1996; DeVore et al. 2005; Greenwood et al. 2005; DeVore and Pigg 2007).

The Okanagan Highlands fossil floras have received varying degrees of attention in the literature. Some sites are relatively well known and described, such as Republic in Washington (e.g., Wolfe and Wehr 1987, 1991; Wehr 1995; Johnson 1996; Wehr and Manchester 1996; Pigg and Wehr 2002; Radtke et al. 2005) and the Princeton chert in British Columbia (e.g., Arnold 1955; Basinger and Rothwell 1977; Cevallos-Ferriz et al. 1991, 1993; Erwin and Stockey 1991; Pigg and Stockey 1996; Little and Stockey 2003; Smith, S.Y. and Stockey 2003; Smith, S.Y. et al. 2006; Little et al. 2009). The Falkland site, however, has received little attention to date, apart from limited mention within the context of regional overviews and some initial descriptions of its insect fauna and palynology (Rice 1959; Archibald 2005; Archibald and Greenwood 2005; Greenwood et al. 2005; Moss et al. 2005).

Taken individually, the Falkland fossil flora contributes to our store of well-preserved macrofloras from a time when many modern plant lineages were undergoing radiation and diversification. However, the Falkland fossil locality has an added value when considered as part of the series of Okanagan Highlands sites. As additional localities in this series receive detailed treatment, the potential to assess the interaction of climate and biota across well-constrained temporal, latitudinal, and altitudinal gradients is enhanced, contributing to a fuller understanding of the regional landscape mosaic in northwestern North America during the warmest period of the Cenozoic.

2.2 GEOGRAPHIC AND GEOLOGICAL SETTING

2.2.1 The Falkland fossil site

The Falkland site (50.516°N, 119.628°W, elevation 1369 m.a.s.l.) and other localities in the Okanagan Highlands series (Fig. 2.1) occur in isolated depositional basins dispersed along a ~1000 km north-south transect from Republic in northern Washington to Driftwood Canyon in west-central British Columbia (Wilson 1980; Archibald and Greenwood 2005). Okanagan

Highlands sites stratigraphically span the EECO, and are contemporaneous with macrofloras from the lowland Puget Group and Chuckanut Formation and their equivalents in BC and Washington (Fig. 2.2).

Tribe (2005) reconstructed paleophysiography of the Early Eocene southern interior of British Columbia as similar in many respects to the modern landscape, being a region of upland plateaus and deeply incised valleys. In contrast to the Recent regional environments, there is little evidence of a southern interior rain shadow in the Eocene fossil record, consistent with a more subdued topography to the west prior to the emergence of the Coast Range (Mathews 1991; Tribe 2005).

The Falkland site is exposed on the southern flank of Estekwalan Mountain, which is comprised primarily of a thick section (>600 m) of Kamloops Group igneous rock resting uncomformably on rocks of the Triassic Nicola and Slocan groups and the Permian Harper Ranch Group that crop out near the base of the mountain (Read 1996; Daughtry and Thompson 2004; Thompson et al. 2006). The Kamloops Group, originally mapped by G.M. Dawson (1895), is a succession of Lower to Middle Eocene volcanic and sedimentary rocks found throughout south-central British Columbia (Ewing 1981; Breitsprecher et al. 2000; Breitsprecher 2002). At the type locality near Kamloops it is comprised of the lower Tranquille and upper Dewdrop Flats formations (Ewing 1981). The Kamloops Group is correlated with the Princeton and Penticton groups to the south (Ewing 1981; Breitsprecher 2002).

Among a number of distinctive units recognized within the Tranquille and Dewdrop Flats formations in the vicinity of the Falkland fossil locality (Read 1996; Breitsprecher 2002; Daughtry and Thompson 2004; Thompson and Beatty 2004), the Falkland site is located within a small outcrop of a rhyolite ash member of the Tranquille Formation which includes a minor shale element. Breitsprecher (2002) described this as a syn-volcanic sedimentary facies found throughout the region, represented elsewhere by units within the Allenby Formation in the Princeton Group and the White Lake Formation in the Penticton Group, both sources of Eocene plant fossil localities (Wolfe et al. 2003). Directly overlying the Falkland fossil locality is a massive to crudely bedded volcaniclastic breccia informally designated the Estekwalan breccia unit of the Tranquille Formation (Breitsprecher 2002). Directly beneath and surrounding the Falkland fossil beds are andesite and basalt lava flows and mudflows of the Dewdrop Flats and Tranquille formations (Thompson and Beatty 2004).

Radiometric dating of the Okanagan Highlands fossil localities has consistently indicated Early to Middle Eocene age (Rouse and Mathews 1961; Mathews 1964; Hills and Baadsgaard 1967; Moss et al. 2005; Villeneuve and Mathewes 2005). Recent U–Pb zircon analysis and ^{40}Ar-^{39}Ar radiometric dating has refined age estimates, which range from 52.08±0.12 Ma for the Hospital Hill locality (Princeton, BC) as the oldest site to 49.42±0.54 Ma for Republic (Washington) as the youngest site (Wolfe et al. 2003; Moss et al. 2005; Villeneuve and Mathewes 2005). The Falkland site has been dated using U–Pb analysis of zircons from interbedded ash layers to 50.61 ± 0.16 Ma (Moss et al. 2005), placing it near the end of the EECO (Fig. 2.2).

2.2.2 Site stratigraphic analysis

A stratigraphic log of the outcrop reveals a lacustrine sequence dominated by finely laminated clay and silt, with periodic influx of coarser material (Fig. 2.3). The outcrop is subdivided here into three informal units on the basis of the vertical extent of the outcrop, prominent volcanic ash layers that can be traced laterally across the site (Fig. 2.4), and biofacies changes (Fig. 2.3 and Table 2.1).

Included with the stratigraphic log is a graph of fossil quality index, developed as part of this study to give a visual indication of fossil quality in the different units and quarries sampled. Fossil quality can reflect a variety of taphonomic factors, including the matrix composition, energy of depositional setting, and degree of transport. During the process of collecting and recording census data, each fossil was designated as poor, well, or very well preserved depending on completeness of the specimen and preservation of details of venation and margin. The fossil quality index (FQ) was determined by the equation:

$$FQ = [(W + V) / n] \cdot 10 \qquad (2.1)$$

where W is the number of well preserved specimens, V is the number of very well preserved specimens, and n is the total number of specimens in the quarry. Quarry size was variable as it was based on convenience sampling, depending on the volume of rock that could be manageably extracted for splitting. Sampling within defined quarries was carried out to provide a mechanism for identifying finer trends within the three units that form the primary sampling units for analysis.

Units 1 and 3 are comprised of similar lithology: finely laminated, dark grey, buff-weathering mudstone or shale, indicating low-energy deposition of sediments on the lake floor.

Unit 3 is more fossiliferous than Unit 1, with a higher FQ value, and contains a very different plant community. The macroflora specimens collected to date suggest a mixed coniferous and broadleaved deciduous forest with a minor broadleaved evergreen element for all three units (Fig. 2.3). However, in Unit 3 the relative abundance of angiosperm fossil specimens relative to gymnosperm specimens increases markedly, from about 50% of specimens in Units 1 and 2, to ~70% of specimens in Unit 3. Unit 2 represents a time of environmental change as reflected in the lake sediments. During the latter part of this period, the lake received an influx of sand, ash, and organic material, perhaps from increased run-off of sediments from the surrounding landscape. Wave ripple marks appear briefly near the base of Unit 2 (Fig. 2.5), coincident with the shift from finely laminated claystone to muddy sandstone, and suggest a change in lake levels and shoreline position.

A distinctive fish-kill layer associated with the wave ripple marks in Unit 2 may indicate either a seasonal mass-death event, or a brief event involving drought and/or flooding (Wilson 1996). Due to the lack of repeated fish-kill events, and the association with wave ripple marks and change in lithology, our interpretation is that this represents an isolated event associated with shifts in precipitation and lake levels, perhaps in association with environmental disturbance by tectonic and/or volcanic activity. Lithology immediately above the fish-kill layer suggests rapid sedimentation with high organic matter and ash content. In addition to the wave ripple marks and the fish-kill layer, Unit 2 contains numerous ash layers, reflecting a period of active volcanism that would have also impacted plant communities at the local and regional levels.

2.2.3 Lacustrine interpretation

Limited exposure (<5m; Fig. 2.3) allows for only generalized characterization of the ancient 'Estekwalan Lake'. Based on visible sedimentary structures, it appears to have been a tectonically controlled balance-filled lake as per the classification of Carroll and Bohacs (1999) and Bohacs et al. (2000). This characterization is suggested by the combination of a lithology dominated by mudstones with some minor siltstone and sandstone, and physical sedimentary structures including fine lamination and the brief appearance of wave ripple marks (Fig. 2.5) indicating a change in lake levels due either to climatic fluctuation or changes in tectonic controls. There is little indication of fluvial input in the visible sedimentary sequence, and conversely no strong indication of evaporative processes. The lake may have been hydrologically closed for at least part of its lifespan, perhaps filling a small depression in the landscape that eventually was covered by the massive Estekwalan breccia.

Analysis of thin sections provides further insights into the character of the ancient lake basin. Tectonic activity in the region is reflected in syndepositional disturbance structures in the form of microfaults (Fig. 2.6), suggesting that some slippage occurred while sediments were in the process of consolidation. In hand specimen some of the Falkland sediments appear banded, suggestive of the presence of annual varves. The presence of varves has been noted at the coeval Okanagan Highlands Horsefly locality (Wilson 1977, 1980). Thin sections of Falkland sediments, however, indicate that laminae are more irregular than expected in varves and are discontinuous laterally. The conspicuous light bands are interpreted as caused by periodic influx of coarser material in the form of thin sheets of sand or ash, and not as evidence of low biological productivity or seasonal ice cover.

2.3 FOSSIL FLORA AND PALEOENVIRONMENT OF THE FALKLAND SITE

2.3.1 Materials and methods

Fossil specimens were collected at the Falkland locality using an unbiased, census approach whereby all specimens encountered within a sampling unit are recorded in order to minimize bias arising from collection of only well preserved, complete, or novel specimens (e.g., Wilf et al. 2003; Iglesias et al. 2007). A large number of specimens (>300) is considered necessary in order to capture patterns in diversity and relative abundance of plant taxa in a leaf fossil compression flora (Burnham 1989; Burnham et al. 1992). Over 1800 compression fossils with stratigraphic context have been recorded at the Falkland site over three field seasons. Numerous additional specimens have been collected from scree to aid systematic analysis and circumscription of morphotypes.

As a first step to understanding fossil plant communities, the Falkland collection has been sorted into discrete morphotypes, which are informal taxonomic categories based on systematically informative morphological and anatomical features (Ellis et al. 2009). Foliage and reproductive organs of both gymnosperms and angiosperms are treated in this manner, although only dicot foliage is subject to the detailed analysis outlined in Ellis et al. (2009), as this material forms the basis for physiognomic estimates of climate. For the present analysis, we use leaf margin analysis (LMA; Wolfe 1979; Wing and Greenwood 1993; Wilf 1997; Kowalski and

Dilcher 2003), leaf-area analysis (LAA; Wilf et al. 1998), and CLAMP (Wolfe 1993) to estimate climatic parameters. Future work will develop floristic estimates of paleoclimate using bioclimatic analysis (Greenwood et al. 2005) in order to compare results from a range of methodologies.

Previous work has compared the plant community composition of Okanagan Highlands sites using checklists and descriptive taxonomic overviews (e.g., Wehr 1995; DeVore et al. 2005; Dillhoff et al. 2005; Greenwood et al. 2005). Here, we build on this information to provide a quantitative assessment of the relative similarity of the Okanagan Highlands floras using the Sørenson coefficient of similarity. As a basis for comparison, we updated the checklist of Greenwood et al. (2005) with preliminary identifications of Falkland taxa from this study, and added some additional taxa collected at the Driftwood Canyon locality in 2008. The Sørenson similarity coefficient was then calculated between a pair of sites:

$$\text{Sørenson coefficient} = 2w/A+B \qquad (2.2)$$

where w is the number of taxa shared between sites, A is the number of taxa in site one, and B is the number of taxa in site 2. The maximum value of the Sørenson coefficient is 1, which would indicate that all taxa are shared between pairs of sites.

As part of the paleoenvironmental reconstruction based on the fossil flora of the Falkland site, we utilize two methods to estimate paleoelevation. The first approach is based on the difference in MAT between sea level and upland sites (Axelrod 1965; Meyer 1992, 2007; Wolfe et al. 1998) and a standardized terrestrial lapse rate:

$$Z = \frac{MAT_{sl} - MAT_{int}}{TLR} + S \qquad (2.3)$$

where Z is the altitude, MAT_{sl} is the MAT at sea level, MAT_{int} is the MAT of the interior assemblage, TLR is the terrestrial lapse rate (the gradient of surface temperature with altitude), and S is ancient sea level relative to modern, for the Early Eocene estimated to be +200 m (Haq et al. 1987). CLAMP, rather than LMA-derived MAT, for Falkland is used for this portion of the analysis in order to provide consistency with previously published data for lowland sites. There is some disagreement over the appropriate TLR to use in this calculation (Meyer 1992, 2007). The worldwide average has been calculated at ~5.5°C/km, but Wolfe has suggested that rates of ~3.0°C/km are more appropriate to the intermontane basins of western North America (Wolfe

1992, Wolfe et al. 1998), and Meyer (1992, 2007) has calculated lapse rates for local areas of western North America that range from 3.6 to 8.1°C/km. We will estimate paleoelevation using both global and regional lapse rates.

The second method for estimating paleoelevation uses differences in enthalpy, a thermodynamically conserved measure of moist static energy in the atmosphere, between sea level and upland sites (Wolfe et al. 1998, Spicer et al. 2003). The difference in enthalpy between sea level and interior sites reflects the difference in potential energy (gZ where g is gravitational acceleration of 9.80665 m/s^2 and Z is height). Enthalpy is one of the climatic parameters estimated by CLAMP, and has been tested in modern settings with robust results (Spicer et al. 2003, 2005). Using both TLR and enthalpy methods, sea level MAT is derived from localities 9841, 9676, and 9677 of the Puget Group of Washington State (Fig. 2.2) which represent Wolfe's Early Eocene Franklinian floral stage (Wolfe 1994; Wolfe et al. 1998). The average CLAMP-derived MAT estimate for these localities is 18.2°C (Wolfe et al. 1998), adjusted to 17.0°C to account for the roughly 3° difference in latitude with Falkland using the Eocene latitude gradient calculated by Greenwood and Wing (1995), assuming similar relative positions in the Early Eocene.

2.3.2 Results

The Falkland locality rivals the better-known Republic (WA) and McAbee (BC) sites in terms of abundance and preservation of plant macrofossils, although the Falkland site is much smaller in volume of outcrop than either. The plant community reflected in the Falkland flora includes a diverse mix of angiosperms (woody dicot trees and shrubs) and gymnosperms. To date 107 morphotypes have been identified: 12 gymnosperm foliage morphotypes; 7 gymnosperm reproductive organ morphotypes (cones, seeds, and cone scales); 2 ferns and fern allies; 1 bryophyte; 66 angiosperm foliage morphotypes (65 dicots and 1 monocot); 15 angiosperm reproductive organ morphotypes; and 4 reproductive organs of unknown affiliation. Detailed systematic investigation of morphotypes and analysis of patterns of diversity will be reported elsewhere. Representative plant macrofossils are shown in Fig. 2.7.

Calculating the Sørenson similarity coefficient between pairs of Okanagan Highlands sites produces the similarity matrix shown in Table 2.2. Falkland is most similar to Republic and McAbee in floristic composition, with coefficients of 0.75 and 0.76, respectively. Republic does, however, contain some meso- to megathermal taxa which appear to be absent from the Falkland site macroflora. Falkland shows least similarity to Horsefly and Driftwood Canyon, with Sørenson coefficients of 0.40 and 0.50, respectively. The sites are listed in latitudinal order in Table 2.2, which reveals a clustering of "northern" (Horsefly and Driftwood Canyon) and "southern" (Republic, Falkland, and McAbee) sites, with Sørenson coefficients of >0.70 for pairs of sites within each cluster. Quilchena is most closely related to the southern cluster but with slightly lower Sørenson values (ranging from 0.63 to 0.69) than for pairs of other sites in this cluster. Quilchena is interpreted as the warmest of the Okanagan Highlands sites (Greenwood et al. 2005), and one of the oldest (Fig. 2.2). It is therefore not surprising to find it similar to, but slightly set apart from, the other southern sites in floristic composition.

Results of the leaf physiognomic analyses of MAT of the Falkland flora are presented in Table 2.3. In all cases, a minimum error of ±2°C has been applied where the calculated binomial sampling error was < 2.0°C (Wilf 1997). Estimates based on equations in Wing and Greenwood (1993) and Wilf (1997) likely underestimate MAT, as they do not take into account the "wet site bias" towards overrepresentation of toothed taxa at low-lying sites with wet soils (e.g., riparian, swamp, and lakeshore vegetation) observed in numerous studies (e.g., Burnham et al. 2001; Kowalski and Dilcher 2003; Greenwood 2005; Royer et al. 2009). The LMA equation proposed by Kowalski and Dilcher (2003), which gives MAT of 8.9 ± 2.0°C for Falkland, compensates for this bias, as it was calibrated using exclusively low-lying wet-soil sites in North America. Although the equation was described as "provisional" by the authors due to the small number of sample sites utilized in the study (10), a more robust predictive equation for North America that takes the wet site bias into account is not yet published. The CLAMP-derived MAT is slightly warmer than the LMA estimates at 11.9 ± 2.0°C, with a coldest month mean temperature (CMMT) estimate of 3.0 ± 2.0°C.

Using leaf-area analysis (Wilf et al. 1998), mean annual precipitation (MAP) is estimated as 114 cm/yr +49 -35 cm. This is the first application of this technique to an Okanagan Highlands flora. MAP values for other Okanagan Highlands sites estimated by bioclimatic analysis typically give estimates of 100–125 cm per year (Greenwood et al. 2005), although with large error estimates. The CLAMP estimates of precipitation for the three wettest and three driest months at Falkland are similar (45± 9 cm and 30±14 cm respectively), and suggest that moisture was distributed fairly evenly over the year with no significant seasonal drought, an interpretation consistent with the sedimentology of the site.

Using the CLAMP-derived MAT estimate of 11.9°C for Falkland, and the adjusted MAT of 17.0°C for the Early Eocene Puget Group localities, the estimated paleoelevation of the Falkland site using eqn. (2.3) is 1.3 ± 0.7 km with the global TLR of 5.5°C/km, or 2.2 ± 1.3 km with a regional TLR of 3.0°C/km. Errors are calculated using the outer bounds of the error ranges of the MAT estimates (± 2.0°C) divided by the TLR. The CLAMP-derived estimate of enthalpy for the Falkland site is 309.8 $kJkg^{-1}$, compared to a sea level estimate for the late Early to early Middle Eocene Puget Group of 323.8 $kJkg^{-1}$ (Wolfe et al. 1998), giving a paleoelevation estimate of 1.4 km with a standard error of 890 m using the enthalpy method (Wolfe et al. 1998), adjusted to 1.6 km to account for Eocene sea level (Haq et al. 1987). This estimate is intermediate between the two estimates from the TLR approach, and is slightly higher than the modern elevation of 1.369 km a.s.l. Thus, the paleoelevation of the site in the Early Eocene is estimated here to be similar to or slightly higher than modern levels, i.e. >1.3 km, which is consistent with Tribe's (2005) reconstruction of the paleophysiography of southern BC.

2.3.3 Discussion

Paleoelevation is an essential component of the paleoenvironmental context for the Okanagan Highlands. As noted by McMillan et al. (2006), there are several potential sources of error in using paleobotanical evidence to estimate paleoelevation. These arise from difficulties in identifying precisely coeval lowland floras, error ranges of MAT estimates, and the assumptions made in regards to terrestrial lapse rates and latitudinal gradients in the past. However, when attempting to reconstruct past environments based on proxy data, it is useful to have several different lines of evidence available in order to cross-check results between different methods (Clark 2007). The TLR and enthalpy methods provide a first-order quantitative estimate of paleoelevation that can be compared to evidence from other proxy or geological data in order to better constrain uplift history of the region and topographical boundary conditions that would have influenced climate.

Results from LMA and CLAMP suggest that MAT was microthermal at the Falkland site (< 13°C), relatively cool for this greenhouse period. This is consistent, however, with an upland character of the site, and is similar to estimates of MAT in the range of 8.0–12.0°C based on physiognomic techniques for the Okanagan Highlands which indicate microthermal paleoclimate (Wing and Greenwood 1993; Wolfe 1994; Wolfe et al. 1998; Dillhoff et al. 2005; Greenwood et al. 2005). Estimates based on bioclimatic analysis tend to yield slightly higher MAT values of 13–15°C, within the lower mesothermal range (Greenwood et al. 2005).

The CLAMP-derived CMMT estimate of 3.0 ± 2.0°C indicates relatively equable climate where frost was not severe. No palm macrofossils have been found at Falkland, although palm fronds are abundant in coeval lowland sites from the Chuckanut Formation (Mustoe and Gannaway 1997; Mustoe et al. 2007). The two lower members of the Chuckanut Formation – Bellingham Bay and Slide (Fig. 2.2) – represent subtropical, coastal plain forests with MATs of 15–16°C and CMMTs of 10–13°C based on CLAMP (Mustoe and Gannaway 1997; Mustoe et al. 2007). While macrofossils of the palm *Uhlia* occur in the Okanagan Highlands Princeton chert (Erwin and Stockey 1994) and *Sabal* palm pollen is abundant at Hat Creek (Moss et al. 2005), the absence of macrofossils and rarity of palm pollen at Falkland and McAbee is consistent with long distance transport from regional sources (Moss et al. 2005). The modern distribution of palms reveals low tolerance for frost and a minimum CMMT of 5°C (Wing and Greenwood 1993; Greenwood and Wing 1995). The Falkland site appears to have fallen just outside of this zone of tolerance.

Figure 2.8 compares MAT and MAP estimates for Falkland with other Okanagan Highlands sites, the lowland Eocene Chuckanut Formation, and modern climate data from a weather station near the Falkland site. The modern regional climate is clearly much cooler and drier than any of the Eocene estimates, with MAP on the order of one-half to one-third that of the Early Eocene Okanagan Highlands. The Okanagan Highlands sites, in turn, are cooler and drier than their lowland Early Eocene counterparts, although the error ranges for the Falkland estimates overlap with those of the lower Chuckanut Formation members, and are virtually indistinguishable from the younger Padden Member. The Padden Member, however, likely reflects cooler temperatures of the later Eocene to Eocene-Oligocene boundary (Mustoe and Gannaway 1997; Mustoe et al. 2007).

The depositional setting and paleoenvironment of the Falkland site indicate a lakeshore setting in a volcanically active landscape. The relatively cool, upland character of the site is reflected in the plant community and in the climate estimates derived from physiognomic analysis of dicot foliage. Based on radiometric dating, the Falkland site falls near the younger end of the temporal series represented by the Okanagan Highlands sites. These factors are consistent with placement of the site in the waning phase of the EECO. Although the MAT was microthermal, the climate was equable and moderately moist, allowing for the development of a diverse plant community.

2.4 CONCLUSIONS

The Falkland fossil flora has previously received only brief mention in the literature. It is introduced here in detail with analysis of a large macroflora collected using an unbiased census methodology, the first time a Canadian macroflora has been analyzed using this approach. The Falkland site is floristically similar to other Okanagan Highlands sites described in the literature, in particular to Republic and McAbee. Precipitation estimates based on leaf physiognomy for the Falkland site confirm that the Okanagan Highlands area was a mesic cool upland during the Early Eocene Climatic Optimum. Paleoelevation of the Falkland site is estimated to have been similar to or slightly higher than modern levels in the Early Eocene (>1.3km), consistent with recent paleophysiographical reconstructions of the southern interior of British Columbia. The Falkland site adds new data to the Okanagan Highlands series of fossil localities that track floristic and paleoclimate developments along latitudinal and temporal gradients during the Early Eocene Climatic Optimum. Data such as these allow for further testing of climate models for the greenhouse climates of the Early Eocene.

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Table 2.1. Facies descriptions for stratigraphic log.

Facies	Description
ShC	Characterized by dark grey, finely laminated claystone (shale) that weathers to buff, and contains well preserved plant fossils. This facies comprises the majority of Units 1 and 3, and likely represents slow, quiet-water deposition of sediments on the lake floor.
ShS	Characterized by finely laminated orange siltstone (shale), this is a slightly higher energy lacustrine deposit which includes more organic debris than ShC. Plant fossils are well preserved in this facies, which comprises the upper portion of Unit 2.
Sa	Characterized by muddy sandstone that is of low density and includes relatively large quantities of ash and organic debris. This material likely reflects a faster sedimentation rate and higher energy deposition, influenced by volcanic activity and increased run-off from the surrounding landscape. Plant fossils are less well preserved than in ShC or ShS.
SaW	This facies has a muddy sandstone matrix, but is characterized by the brief appearance of sharp-crested wave ripple marks (Fig. 2.5), indicating shallow-water, low-energy nearshore deposition. In addition, a distinctive fish-kill layer containing abundant whole and disarticulated fish remains and a depauperate flora is found in association with the wave ripple marks.
V	Volcanic ash, various grain sizes and bedding.
M	Characterized by dark grey, silty mudstone that is blocky and not fissile. This facies falls primarily outside of the strata sampled for plant fossils.

Table 2.2. Similarity matrix based on Sørenson's coefficient for Okanagan Highlands sites. Floristic checklist data from Greenwood et al. (2005) and sources quoted therein, with addition of preliminary identifications for Falkland from this study. One-Mile Creek/Princeton has been excluded from the comparison due to amalgamation of several sites in the Princeton area in the original data. The Driftwood Canyon list has been updated to include additional taxa collected by the authors in 2008. Fossil floras are listed from northernmost site (Driftwood Canyon) to southernmost site (Republic), as per Fig. 2.1.

	Driftwood Canyon	**Horsefly**	**McAbee**	**Falkland**	**Quilchena**	**Republic**
Driftwood Canyon	*	0.72	0.47	**0.50**	0.48	0.38
Horsefly	0.72	*	0.47	**0.40**	0.41	0.43
McAbee	0.47	0.47	*	**0.76**	0.68	0.76
Falkland	0.50	0.40	0.76	*	0.64	0.75
Quilchena	0.48	0.41	0.68	**0.64**	*	0.63
Republic	0.38	0.43	0.76	**0.75**	0.63	*

Table 2.3. MAT estimates for the Falkland site based on physiognomic analysis.

Method	Reference	MAT estimate ± 2°C
<u>Simple linear regression</u>		
$MAT=1.141+(30.6\bullet P_{margin})$	Wing and Greenwood 1993	6.8
$MAT=3.25+(24.4\bullet P_{margin})$	Wilf 1997 (CLAMP "warm sites")	7.8
$MAT=2.223+(36.3\bullet P_{margin})$	Kowalski and Dilcher 2003	8.9
<u>Canonical Correspondence Analysis</u>		
CLAMP	Wolfe 1993	11.9

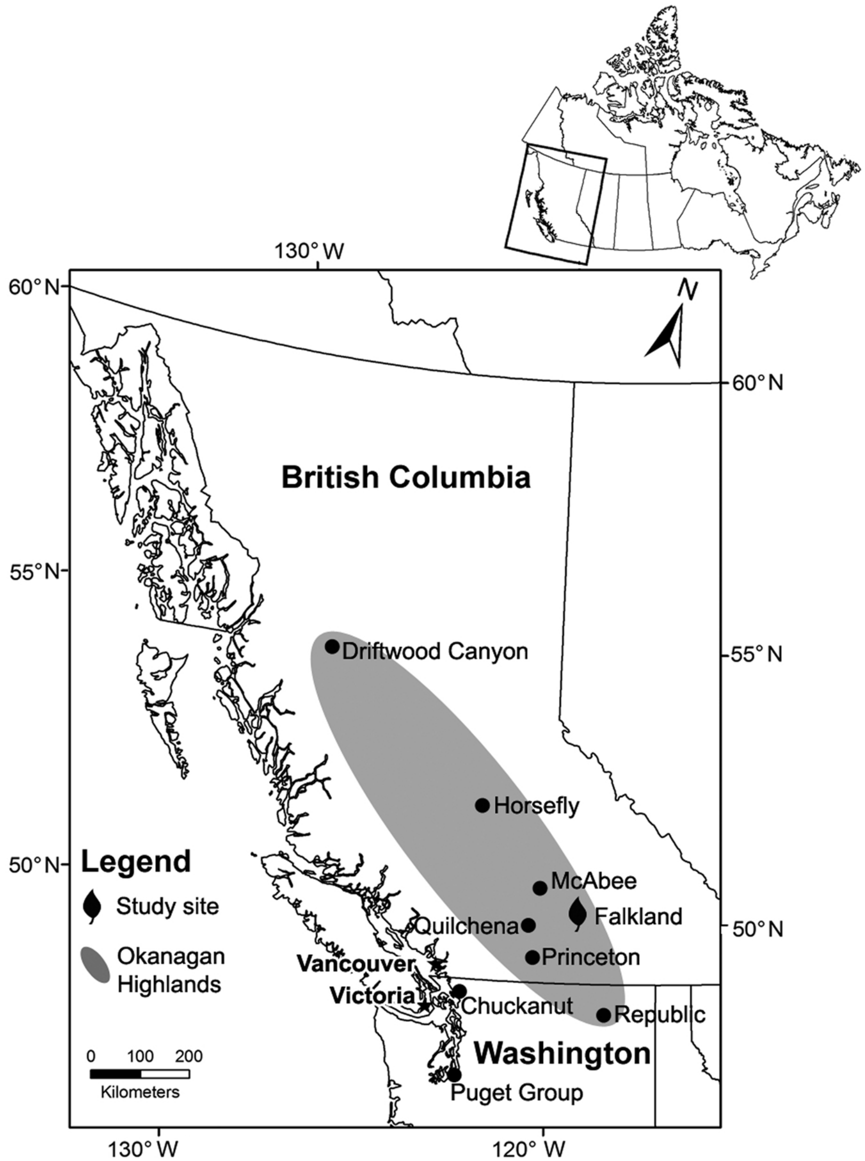

Fig. 2.1. Map showing location of early Eocene fossil sites of the Okanagan Highlands and coeval lowland floras.

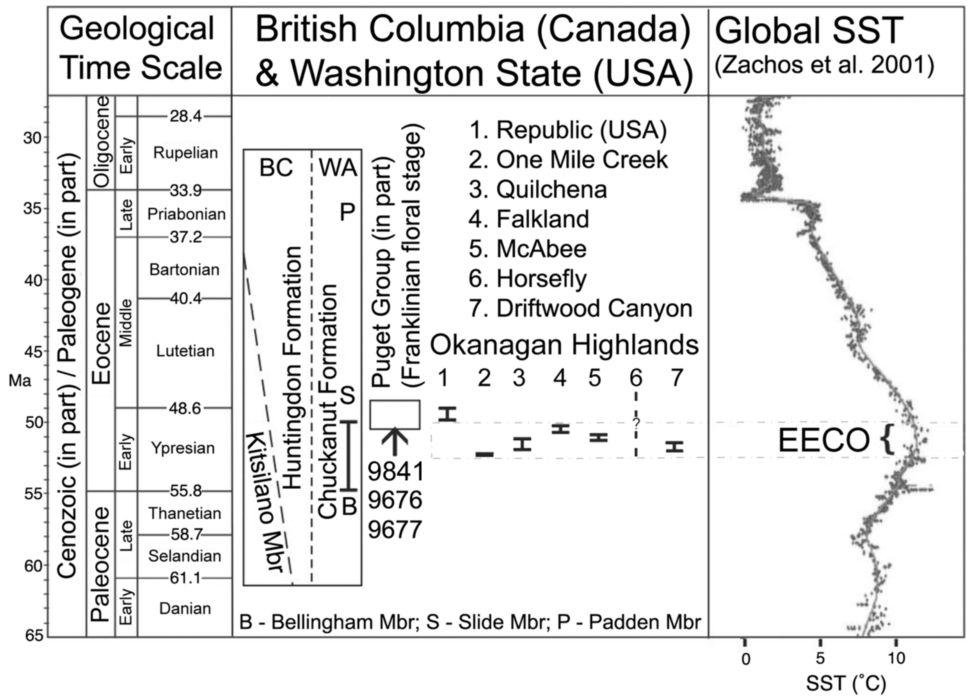

Fig. 2.2. Correlation chart showing age of fossil sites and climate trends in the early Paleogene. EECO, Early Eocene Climatic Optimum; SST, sea surface temperature; 9841, 9676, 9677, Puget Group locality numbers (Wolfe et al. 1998). Geochronology from Ogg et al. (2008); Okanagan Highlands data from Greenwood et al. (2005) and sources therein; Chuckanut and Huntingdon Formation ages from Mustard and Rouse (1994) and Mustoe and Gannaway (1997); Puget Group data from Wolfe et al. (1998).

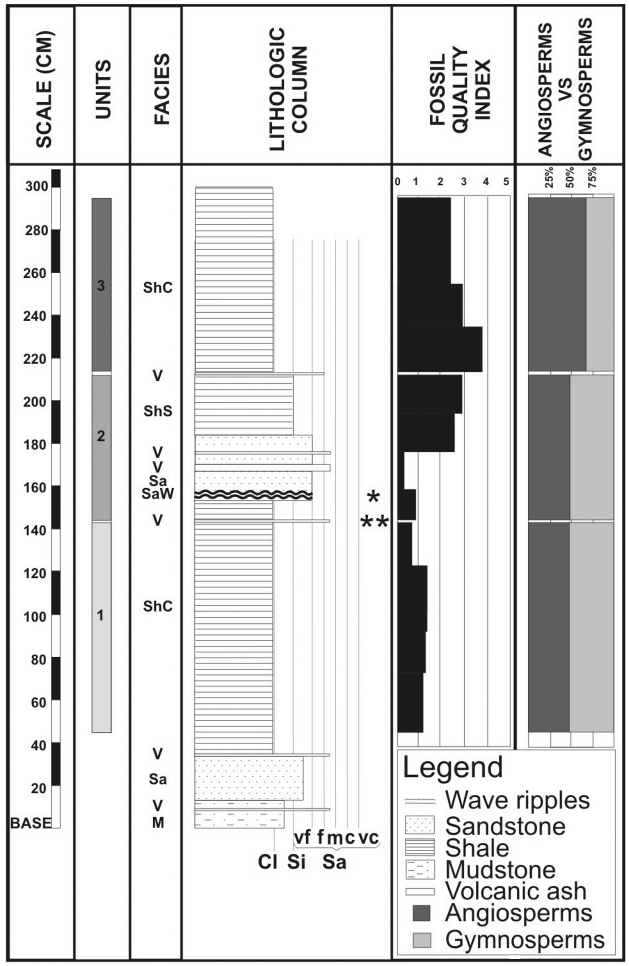

Fig. 2.3. Stratigraphic log of the Falkland site outcrop showing units, facies, lithology, fossil quality index, and proportion of angiosperm and gymnosperm specimens in the three units. Fossil quality (FQ) index scale truncated to 5 (from maximum 10). ShC, shale-claystone; ShS, shale-siltstone; Sa, sandstone; SaW, sandstone-wave rippled; M, mudstone; V, volcanic ash; ** location of datum ash (Fig. 2.4); * location of wave ripples (Fig. 2.5).

Fig. 2.4. Datum ash layer used for correlation across the outcrop, measurement of quarry position, and source material for radiometric dating. Scale bar in cm.

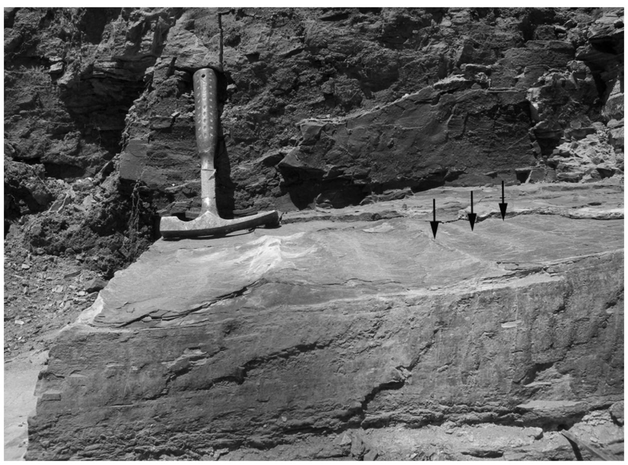

Fig. 2.5. Wave ripple marks in Unit 2 (crests indicated by arrows). Hammer for scale.

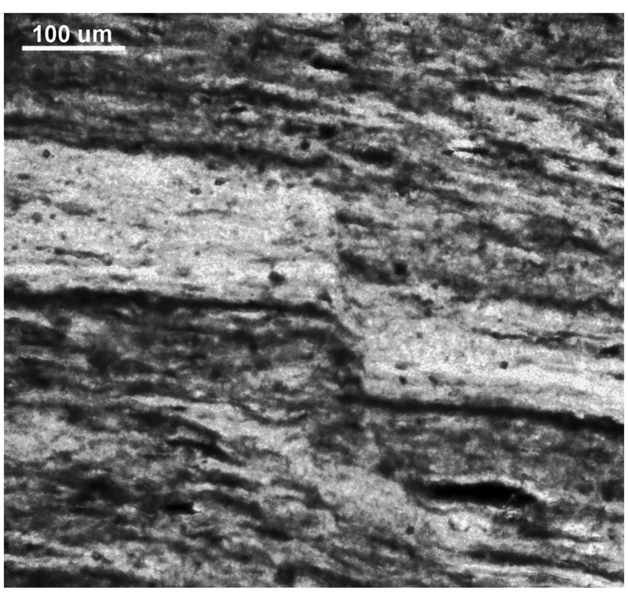

Fig. 2.6. Thin section through lake sediment hand specimen showing microfault cutting through false varves.

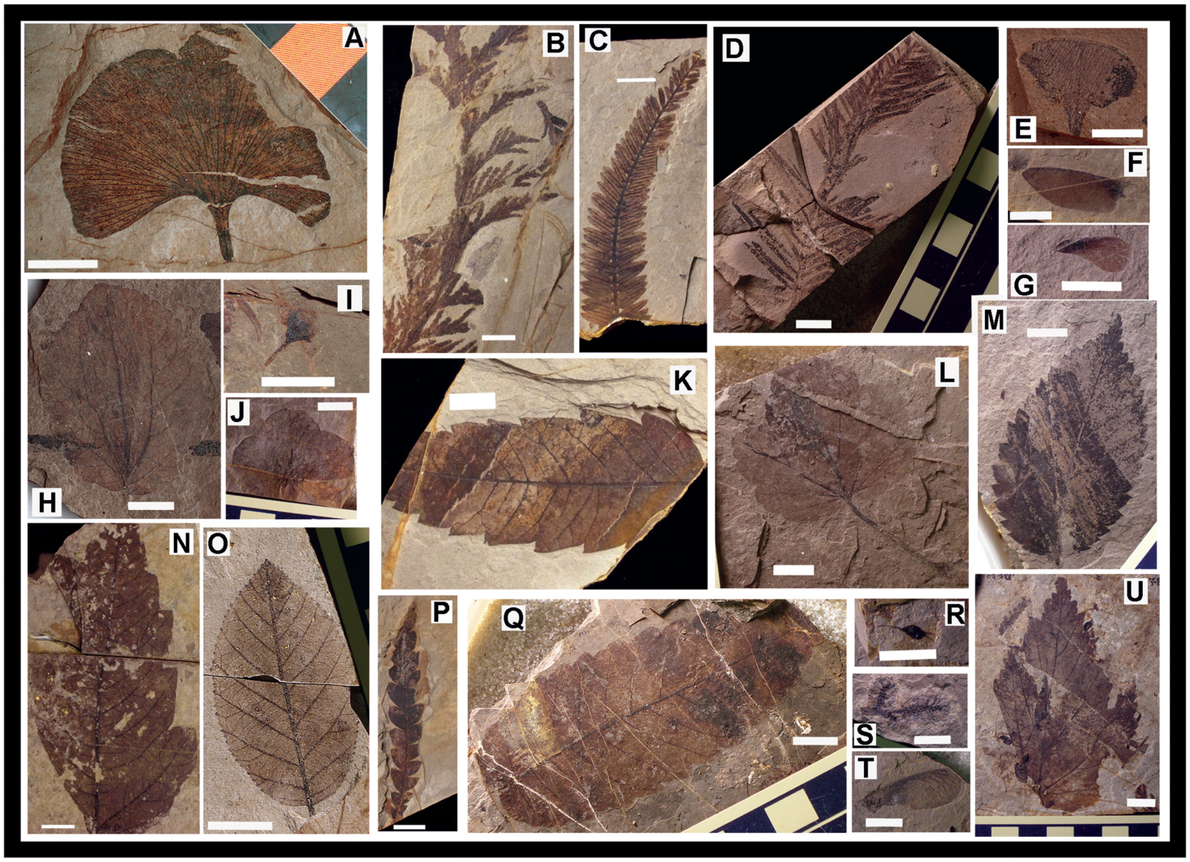

Fig. 2.7. Examples of plant macrofossils from the Falkland site. All scale bars 1 cm. (A) *Ginkgo adiantoides*; (B) Cupressaceae sp. foliage; (C) *Metasequoia occidentalis*; (D) *Abies milleri* foliage; (E) *Abies milleri* cone scale; (F) *Pinus* sp. seed; (G) *Picea* sp. seed; (H) *Cercidiphyllum* sp.; (I) *Trochodendron* sp. fruit; (J) *Florissantia quilchenensis* flower; (K) *Rhus malloryi*; (L) *Ribes* sp.; (M) *Ulmus okanaganensis* (elongation-shoot leaf); (N) *Bohlenia americana*; (O) *Alnus parvifolia*; (P) *Comptonia columbiana*; (Q) *Ulmus okanaganensis* (sucker-shoot leaf); (R) *Ulmus* sp. fruit; (S) *Alnus parvifolia* catkin; (T) *Acer* sp. samara; (U) *Acer* sp.

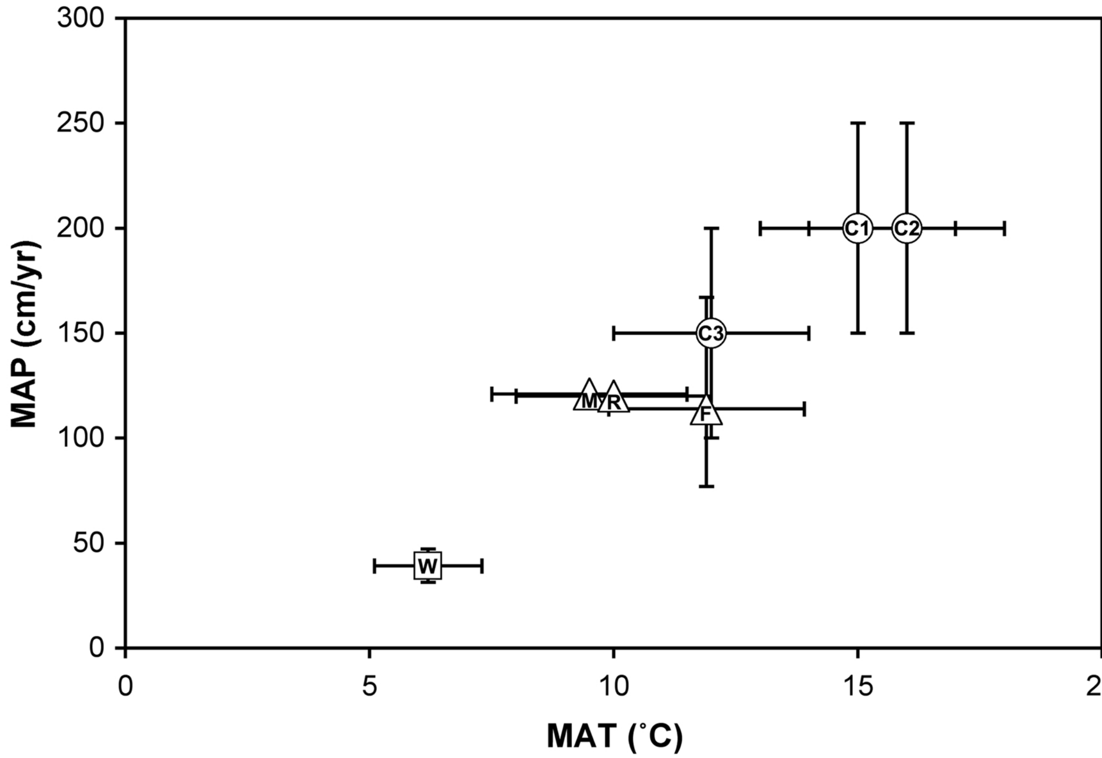

Fig. 2.8. Comparison of MAT and MAP estimates for select upland Okanagan Highlands fossil localities (F, Falkland; R, Republic; M, McAbee), lowland Chuckanut Formation fossil localities (C1, Bellingham Bay Member; C2, Slide Member; C3, Padden Member), and a modern weather station (W, Westwold, 50˚28.200 N, 119˚45.000 W, elevation 609 m). All MAT values based on CLAMP analysis; MAP values as stated in sources listed, except Falkland (calculated using leaf area analysis, this study). Westwold values are climate normals from observed values 1971-2000. Sources of information: Falkland (this study), Republic (Wolfe and Wehr 1991, Wolfe et al. 1998); McAbee (Dillhoff et al. 2005); Chuckanut (Mustoe and Gannaway 1997);
Westwold (www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html).

3. ESTIMATING PALEOATMOSPHERIC *p*CO_2 DURING THE EARLY EOCENE CLIMATIC OPTIMUM FROM STOMATAL FREQUENCY OF *GINKGO*, OKANAGAN HIGHLANDS, BRITISH COLUMBIA, CANADA[2]

Abstract: Estimates of *p*CO_2 for the early Paleogene vary widely, from near modern-day levels to an order of magnitude greater, based on various proxy measures. Resolving the relationship between climate and *p*CO_2 during this globally warm period is a key task in understanding climate dynamics in a warmer world. Here, we use the stomatal frequency of fossil *Ginkgo adiantoides* from the Okanagan Highlands of British Columbia, Canada to estimate *p*CO_2 during the Early Eocene Climatic Optimum (EECO), the interval of peak warmth in the Cenozoic. We also examine a dataset of modern *Ginkgo biloba* leaves to critically assess the accuracy and precision of stomatal frequency as a proxy indicator of *p*CO_2. Early Eocene fossil *G. adiantoides* has significantly lower stomatal frequency than modern *G. biloba*, suggesting *p*CO_2 levels >2× modern pre-industrial values. This result is in contrast to earlier studies using stomatal frequency of *Ginkgo* that indicated near modern-day levels of *p*CO_2 in the early Paleogene, though not including samples from the EECO. We also find that levels of *p*CO_2 as indicated by stomatal frequency are correlated with trends in climate (mean annual temperature) over time at the Falkland fossil locality, suggesting that climate and *p*CO_2 were coupled during the EECO hyperthermal.

3.1 INTRODUCTION

The Early Eocene Climatic Optimum (EECO), ca. 53–50 Ma, was the warmest interval of the Cenozoic, indicated by multiple proxy mean annual temperature estimates for sea and land surfaces (Zachos et al., 2001, 2008). However, estimates of *p*CO_2 during the early Eocene from geochemistry (Demicco et al., 2003; Yapp, 2004; Lowenstein and Demicco, 2006), modeling (Berner and Kothavala, 2001; Thrasher and Sloan, 2009), and paleobotanical proxies (McElwain, 1998; Kürschner et al., 2001; Retallack, 2001; Royer et al., 2001; Greenwood et al., 2003; Royer, 2003) show a wide range of values, from near modern-day levels to an order of magnitude

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greater. In part, the variability in estimates may reflect high oscillations in pCO_2 during this time period (Pearson and Palmer, 2000; Demicco et al., 2003). However, the differences in estimates may reflect real issues of accuracy and precision with various proxy datasets. Climate models at global and regional scales have been unable to produce simulations that reconcile both CO_2 levels and climate estimates from paleontological data for the early Eocene (Thrasher and Sloan, 2009). Resolving the pCO_2 record for this time period, and thereby correlating it with trends in temperature, is a key task in understanding the interaction of climate and pCO_2 in globally warm periods.

Greenhouse periods in Earth history provide the best available evidence for developing and refining models to predict future impacts of global climate change on terrestrial ecosystems (Royer, 2008; Zachos et al., 2008). Therefore, the development of paleobotanical proxy measures of paleoenvironmental parameters has received growing attention in recent years, as have concerns over both accuracy and precision of these proxies (Royer, 2001, 2006; Greenwood, 2007). One such proxy measure is the stomatal frequency of land plants, which has been shown in some species to vary inversely with atmospheric pCO_2 (Woodward, 1987), and has been used to estimate paleo-pCO_2 for multiple geological time periods, including the Paleozoic (e.g. McElwain and Chaloner, 1995; Beerling, 2002), the Mesozoic (e.g. McElwain and Chaloner, 1996; McElwain et al., 1999; Haworth et al., 2005; Passalia, 2009; Quan et al., 2009; Barclay et al., 2010), and the Cenozoic (e.g. Beerling et al., 1992; Van Der Burgh et al., 1993; Royer, 2003; Kürschner et al., 2008). Given the potential practical applications in refining and testing climate models, there is a need to expand the available datasets as well as to critically assess the validity of this proxy. This paper applies the stomatal frequency technique to estimating paleo-pCO_2 during the EECO using fossil material of *Ginkgo adiantoides* (Unger) Heer from the Falkland macroflora, part of the Okanagan Highlands series of fossil localities in British Columbia, Canada (Fig. 3.1; Greenwood et al., 2005; Moss et al., 2005; Smith et al., 2009). In addition, we explore the issue of natural variability in modern populations of *Ginkgo biloba* L., expanding on earlier work by Chen et al. (2001) and Sun et al. (2003).

3.2 BACKGROUND

Studies based on historical herbarium material and fossil leaves, as well as experimental studies under CO_2 enrichment (or depletion), have shown a general, though not universal, inverse relationship between CO_2 levels and stomatal frequency (for a review see Royer, 2001). Stomata are the controlled pores through which plants exchange gases with their environments, and play a key role in regulating the balance between photosynthetic productivity (rate of carbon uptake) and water loss through transpiration. Stomatal response to atmospheric pCO_2 varies by species, suggesting caution in comparing data across taxonomic boundaries (Salisbury, 1927; Royer, 2001; Beerling and Royer, 2002b; Greenwood et al., 2003; Royer, 2003; Sun et al., 2003). Therefore, studies tracking correlations between stomatal frequency and CO_2 levels should, as far as possible, be based on single-species correlations and ideally under similar habitat conditions (Beerling and Chaloner, 1992; Beerling and Royer, 2002; Greenwood et al., 2003; Royer, 2003; Haworth et al., 2010). Difficulty in identifying appropriate modern analogs for fossil taxa at the species level presents a significant obstacle in the extrapolation of paleoclimate signals from stomatal characteristics in fossil material. For this reason, stomatal frequency of the "living fossil" *Ginkgo biloba* in combination with its fossil analogs is often used in applications of this technique, as there is little evidence of morphological change in this lineage since the Cretaceous (Royer et al., 2003).

Stomatal frequency in *G. biloba* has been shown to vary inversely with atmospheric pCO_2 in experimental studies and in studies based on herbarium material representing the past 150 years, where pCO_2 levels are known (Beerling et al., 1998; Royer, 2003; Beerling et al., 2009). Based on this observed inverse relationship, several studies have used fossil *Ginkgo* to estimate paleo-pCO_2 for various time periods in the Mesozoic and Cenozoic. Beerling et al. (1998) found that *Ginkgo* from the Triassic and Jurassic showed stomatal frequencies similar to *G. biloba* grown under moderately enriched pCO_2 (560 ppmV) in experimental trials, and significantly lower stomatal frequency compared to *G. biloba* grown under ambient pCO_2. The Mesozoic is generally recognized as a warm period in Earth history, and thus these results suggest a coupling of elevated pCO_2 and temperatures during this period. Passalia (2009) found evidence of modest levels of enrichment of pCO_2 (466–777 ppmV) in the Lower Cretaceous, (~117–120 Ma) based on Ginkgoales, but found higher pCO_2 levels indicated by stomatal frequencies of other taxa for this time period. Quan et al. (2009) inferred a gradual decline in pCO_2 during the Campanian (Late Cretaceous) based on the stomatal index (SI) of *G. adiantoides* from China, with background levels of pCO_2 higher than modern at ~550– 590 ppmV. In addition, they observed short-term fluctuation in pCO_2 during the upper Campanian, with a transient increase to ~690 ppmV.

Royer and colleagues (Royer et al., 2001; Royer, 2003) used *Ginkgo* to track pCO_2 levels for the early Paleogene (Paleocene to early Eocene, ca. 65–53 Ma), another warm period in Earth history (Zachos et al., 2001, 2008). Their results indicated that pCO_2 levels were similar to the present day (between ~300 and 450 ppmV), suggesting that factors other than pCO_2 may have been at work in forcing climate. Recently, however, Beerling et al. (2009) revisited this dataset with a revised statistical approach to estimating paleo-pCO_2 from fossil leaves and quantifying uncertainty. The application of their method resulted in an upward revision of these estimates by 150 to 250 ppmV, suggesting pCO_2 levels of ~450 to 700 ppmV for the early Paleogene from the same fossil dataset. Retallack (2001) found much higher levels of atmospheric pCO_2 in the early Paleogene (~1500–4500 ppmV) based on stomatal frequency of *Ginkgo*, but used a different transfer function than Royer and colleagues. However, Retallack's study relied on previously published images of *Ginkgo* cuticle (representing an unknown range of variability within samples) and in some cases utilized fewer than five leaf fragments to obtain average counts, which is the minimum number deemed adequate by most workers in the field (Beerling and Royer, 2002; Royer, 2003; Quan et al., 2009). In addition, the pCO_2 estimates in some cases are based on a transfer function that extrapolates beyond the range of the training set data, and therefore may be unreliable (Royer, 2003).

Previous studies applying the *Ginkgo* stomatal frequency technique to the early Eocene have not included well-dated samples from the EECO hyperthermal. Royer's (2003) dataset included one specimen that may date to the Paleocene Eocene Thermal Maximum (PETM), a brief and abrupt warming event ca. 55 Ma (Zachos et al., 2001), and this specimen indicated elevated pCO_2 (826 ppmV) compared to the other early Paleogene samples. However, Royer (2003) noted that the specimen could not be firmly dated to the PETM, and further that it represented a different species of *Ginkgo*, *G. gardneri* Florin, rather than *G. adiantoides*. Since *G. gardneri* is not considered an equivalent of *G. biloba* (Denk and Velitzelos, 2002) this could explain the different values. Here, we use specimens of *G. adiantoides*, considered by many authors to be conspecific with modern *G. biloba* (Tralau, 1968; Royer et al., 2003), from the Falkland site in the southern interior of British Columbia, Canada (Fig. 3.1). The Falkland locality has been dated at 50.61 ±0.16 Ma by U-Pb analysis of zircons from interbedded ash layers, an age consistent with the palynoflora (Moss et al., 2005), placing it in the waning phase of the EECO. The Falkland locality is part of a series of correlative sites in British Columbia and Washington State known as the Okanagan Highlands (Fig. 3.1; Greenwood et al., 2005; Smith et al., 2009).

3.3 MATERIALS AND METHODS

Stomatal frequency can be measured as either stomatal density (SD), the number of stomatal pores per unit area of leaf, or as a stomatal index (Salisbury, 1927; Royer, 2003). Stomatal index (SI) is defined as the percentage of epidermal cells that are stomatal complexes (comprised of guard cells and the stomatal aperture) as per the equation:

$$SI\ (\%) = \frac{SD}{SD + ED} \times 100 \qquad (3.1)$$

where SD is stomatal density and ED is epidermal cell density for a given leaf area.

For obtaining stomatal frequency counts from both modern and fossil cuticles, a 300 μm x 300 μm quadrat was superimposed on the image of the cuticle surface (following preparation as described below), and all epidermal cells and stomatal complexes were counted within that quadrat. A cell or stomatal complex was counted if it was at least half within the quadrat boundary. Guard cells were included in the stomatal complex, and subsidiary cells were counted as epidermal cells. Three fields of view were counted for each leaf fragment. For statistical analyses, all tests were run at α=0.05, and rounding was only applied at the last step of all calculations. Reported errors for stomatal frequencies are 95% confidence intervals (standard deviation and standard error also reported in Table 3.1).

3.3.1 Extant specimens

Modern leaves used in the present study were collected in May, 2004 from five individual *G. biloba* trees growing in a single stand on the grounds of the University of New South Wales, Sydney, Australia. Leaves were collected from both short and long shoots, from a variety of aspects and heights (Fig. 3.2). Leaves were collected, pressed and dried in a plant press according to standard techniques. A variety of methods were explored for the preparation of cuticle from modern *G. biloba,* including the use of cellulose acetate replicas, cuticle maceration, and scanning electron microscopy of cleared cuticle.

The cellulose acetate method was adapted from Beerling et al. (1992) and involved flooding the leaf surface with acetone and applying a sheet of cellulose acetate to create the replica. Small squares (~ 0.5–1.0 cm^2) were then cut from the middle region of the resulting impression. These fragments were dry mounted on slides and viewed on a Zeiss Axioplan Microscope under 200x magnification linked to a computer with MetaView Imaging System software (Fig. 3.3).

Maceration was the second method used to process the modern *Ginkgo* leaves. The leaf pieces were soaked overnight in 95% ethanol. The following day they were placed in a simmering bath of 20% H_2O_2 until the cuticle envelope began to separate (approximately 6 hours). The cuticle was then removed from the oxidizing agent, rinsed in 1% ammonium hydroxide, and then cleaned with a fine brush under a dissecting microscope. For viewing under transmitted light, the cleared cuticle was stained with Safranin O. A differential interference contrast (DIC) filter was used to improve the contrast of the cuticle surface (Fig. 3.4). Leaves were processed using both the acetate peel and maceration techniques in order to create two datasets to assess consistency of results. Five leaves per tree (=25 leaves) were assessed via both techniques as per standard protocols (Royer, 2003), with an additional 5 leaves assessed for the cuticle maceration dataset. For SEM imagery, macerated cuticle samples were mounted on aluminum stubs, coated using an Edwards S150B Gold Sputter Coater, and viewed using a JEOL JSM-840A scanning electron microscope. The SEM images were used for fine examination of stomatal and epidermal features (Fig 3.5).

3.3.2 Fossil specimens

The fossil specimens in this study were collected during three field seasons (2006–2008) at Falkland, British Columbia (Fig. 3.1). Specimens were collected as part of a systematic sampling effort that utilized an unbiased census approach. Three units were recognized within the outcrop on the basis of laterally continuous volcanic ash layers, the extent of the exposed outcrop, and changes in lithology (for further details of sampling and collecting methodology, see Smith et al., 2009). *Gingko adiantoides* was one of the most common taxa at the site, accounting for ~12% of recorded specimens in Units 1 and 2, dropping to ~4% of specimens in Unit 3.

Several techniques were explored for examining the fossil cuticle, including maceration (and subsequent viewing with light and scanning electron microscopy) and viewing of unaltered cuticle under epifluorescence. Maceration followed the protocol of Kouwenberg et al. (2007), whereby cuticle was transferred from the rock matrix using polyester overlays, and then treated with HCL, HF, H_2O_2 and bleach. For SEM imagery, macerated cuticle samples were mounted on aluminum stubs and prepared as described above for the modern samples. The SEM images were used for fine examination of stomatal and epidermal features (Fig. 3.6), but generally were not sufficient for calculating stomatal frequency due to the difficulty in distinguishing the borders of the abaxial epidermal cells.

To utilize epifluorescence microscopy, unprepared leaf surfaces were viewed directly using an Olympus MVX10 Macro Zoom Research Microscope equipped with a GFP filter (BP460-480HQ excitation filter). The advantages of the epifluorescence approach include time effectiveness (essentially no pre-treatment of the fossil specimen), avoidance of harsh chemicals, conservation of the fossil specimen (i.e. non-destructive technique), and the ability to rapidly scan the entire surface of the specimen to locate the areas of best cuticle preservation (Fig. 3.7). For these reasons, the epifluorescence method was used to obtain stomatal frequency counts for the fossil specimens. Three fields of view were counted per specimen, and in total 14 specimens were analyzed for the Falkland site, with four from Unit 1, and five each from Units 2 and 3.

3.4 RESULTS

The cellular architecture of *Ginkgo* epidermal cells, which are typically papillose on the abaxial, stomata-bearing surface, makes it difficult to consistently and accurately count the epidermal cells, as the papillae tend to obscure the cell wall boundaries (Fig. 3.3). Stomata, however, are for the most part easily identified. Therefore, while SD could be determined for virtually all samples, it was rarely possible to calculate SI with confidence. This was true for both modern and fossil specimens. It is important to recognize this limitation, as it has a significant bearing on the determination of pCO_2 estimates derived from SI values (see Discussion).

3.4.1 Extant specimens

A summary of stomatal frequencies of the modern *G. biloba* samples for two datasets (acetate peel replicas and macerated cuticle) is provided in Table 3.1. SD values were calculated for all samples in the two datasets. For the purposes of discussion and comparison with other studies, SI values were determined for all of the modern acetate-peel samples, although confidence in the accuracy of these values is low for the reasons described above. For the macerated modern cuticle, SI was calculated where deemed possible. In most cases, the same leaves were used to calculate the values in the two datasets; however, for the macerated cuticle an additional leaf was sampled per tree in order to provide equal numbers of long- and short-shoot leaves. Preliminary results from blind counts with the acetate peel dataset suggested that there were significant differences between the stomatal frequencies of long- and short-shoot leaves; therefore, sample size was adjusted in the second dataset in order to better test this result. The purpose in studying two datasets was to assess the consistency of the stomatal frequency counts between preparation methods.

Using the leaf average values (average of three fields of view counted for each leaf), there is no significant difference between the SD measurements from the 25 leaves using the acetate peel method and the SD measurements of the 30 leaves using cleared and stained cuticles (two sample *t*-test assuming equal variance, p=0.740 for leaf averages). This was true for the population of trees as a whole, and also on a tree-by-tree comparison, and when comparing separately the values for long- and short-shoot leaves in the two datasets. Stomatal density values are 97±5 mm^{-2} calculated from acetate peels and 95±5 mm^{-2} calculated from cleared cuticles (Table 3.1), and compare well with other published results (Table 3.2) for contemporary *Ginkgo biloba*. This observation provides a measure of confidence in the accuracy of these SD values, as significant differences would suggest observational errors or significant natural variation.

Stomatal index values were compared between the two datasets in the same manner as discussed above, although there were relatively fewer samples from the macerated cuticle data as these were counted more selectively. Significant differences were found between the SI calculated from acetate peels, and the SI calculated from macerated cuticle (p=0.01 based on leaf averages). The mean SI value for the acetate peels is 9.5±0.5, and from macerated cuticle is either 10.9±0.5 (using only those leaves where SI for three fields of view could be calculated to obtain a leaf average) or 10.7±0.5 (using average of all field-of-view counts). The average SI from the acetate peel dataset fits fairly well within the range of published values for *G. biloba,* although the macerated cuticle dataset value is somewhat high (Table 3.2).

Comparisons were made among the five trees for the two data sets (acetate peels and macerated cuticle) using single factor one-way ANOVA. Using the acetate peel data, variation among the five trees was not found to be statistically significant in terms of SD or SI using leaf average counts (for SD $p=0.396$; for SI $p=0.607$). For the macerated cuticle dataset, the analysis was only run on SD values, as there were not enough samples for which leaf average SI values could be calculated for each tree. There was no significant difference between the SD of the five trees using leaf average counts, based on single factor one-way ANOVA ($p=0.103$). These results suggest that stomatal frequency is consistent in this single population of five modern trees.

G. biloba produces leaves on both short and long shoots. Leaves on long shoots are widely spaced, helically arranged, and form and develop in the same growing season. In contrast, leaves on short shoots are borne closely together, and develop the season following the one in which they are initiated within overwintering buds (Chen et al., 2001). Although short-shoot leaves outnumber long-shoot leaves on a tree, approximately equal numbers of leaves were collected from short shoots and long shoots, allowing the possibility of comparing their values.

A *t*-test was used to compare the mean stomatal frequencies of the two kinds of leaves. Results show significant differences between the SD of long- and short-shoot leaves ($p=0.001$ in the acetate peel dataset, and $p=0.003$ in the macerated cuticle dataset). This difference is clearly evident in the average SD values for long and short shoots, with average SD of short-shoot leaves 87 ± 6 mm^{-2} from acetate peels, and 85 ± 5 mm^{-2} from macerated cuticle; and SD of long-shoot leaves 107 ± 7 stomata mm^{-2} and 105 ± 7 stomata mm^{-2} in the two respective datasets. Stomatal frequency for each leaf was determined without knowledge of whether the leaf was from a short or long shoot (i.e. blind counts). SI values were significantly different between long- and short-shoot leaves in the acetate-peel data set ($p<0.0001$). The macerated cuticle dataset contained relatively few samples for which the leaf average SI from three field of view counts could be determined (12 out of 30 leaves). Within this small set, there was no significant difference between SI of long- and short-shoot leaves ($p=0.385$) based on leaf averages. In general, then, short-shoot leaves tend to have significantly lower SD and SI values than long-shoot leaves.

These results are borne out visually in a scatter plot showing the distribution of SI to SD for leaves from long shoots and short shoots (Fig. 3.8A) for the acetate peel dataset. In contrast, Fig. 3.8B is a scatter plot of the same data separated by tree, rather than by long or short shoot status, and shows no clearly defined clusters, confirming that the important difference is between long- and short-shoot leaves, rather than individual trees. Overall, results from extant *G. biloba* indicate that SD is more likely to be accurately determined than SI, that natural variation in stomatal frequency among the five trees in this stand is not significant, but that there is a significant difference in stomatal frequency of long- and short-shoot leaves.

3.4.2 Fossil specimens

Epidermal features preserved in the fossil specimens (Fig. 3.6) are consistent with those described by Denk and Velitzelos (2002) for *G. adiantoides*. The epidermal cells on the adaxial surface display undulate anticlinal cell walls, and lack papillae and stomata (Fig. 3.6B). Cells over veins tend to be elongate and rectangular, while those in intercostal areas vary in shape from isodiametric to rectangular or polygonal (Fig. 3.6B). These characters are shared with modern *G. biloba* (Fig. 3.5B), although in extant *Ginkgo* stomata on the adaxial surface are occasionally present (Fig. 3.5D). Abaxial epidermal cells are papillate, and the subsidiary cells surrounding the stomata are strongly papillate, to the point of almost occluding the stomatal pore in some cases, and are amphicyclocytic in arrangement (Fig. 3.6D). Again, these features are generally shared with extant *G. biloba*, although modern *Ginkgo* shows some variation in the papillate nature of subsidiary cells (Denk and Velitzelos, 2002).

The average SI for fossil *Ginkgo* at the Falkland site based on 14 specimens (3 field of view counts for each specimen) is 5.8 ±0.4, and average SD is 60±4 mm^{-2} (Table 3.1; error expressed as 95% confidence interval). Figure 3.9 plots the results of this study against published SI values for *Ginkgo* from the early Paleogene. In contrast, Table 3.2 shows published SI and SD values for modern *G. biloba*, which are much higher than the early Eocene values reported here, indicating that $p\mathrm{CO}_2$ levels were elevated during the EECO with respect to modern values. Stomatal frequencies were also calculated for samples from each of the three units, and show a trend of increasing values (Fig. 3.10; Table 3.1), suggesting a decline in $p\mathrm{CO}_2$ over the time period represented by this site (likely on the order of 10^3–10^4 yr). Concurrently, mean annual temperature (MAT) was declining, as estimated by leaf margin analysis on fossil specimens from the three units at Falkland (Fig. 3.11).

3.5 DISCUSSION

Calibrations of the stomatal frequency of *G. biloba* to changing $p\mathrm{CO}_2$ have resulted in the development of several non-linear transfer functions and other statistical methods that can be used to estimate pCO_2 based on the SI of fossil *Ginkgo* (McElwain, 1998; Retallack, 2001; Royer et al., 2001; Beerling and Royer, 2002b; Royer, 2003; Beerling et al., 2009). However, the average fossil SI from this study is outside the useful range of the available training sets. Beerling et al. (2009) caution against inserting fossil SI values into calibration equations in cases such as this, as the extrapolation required will likely lead to unreliable estimates, thereby undermining the utility of the proxy. Although the mean fossil SI value reported here can therefore not be used directly with existing calibrations, the upper error limit of the fossil SI value (6.26 based on 95% confidence interval from raw data, see Table 3.1) falls within the error range of the smallest SI value of training set data (smallest SI value in the training set is 6.67 from an experimental trial under enriched CO_2 of 801 ppmV; Royer et al., 2001; Royer, 2003; Beerling et al., 2009), and can therefore be used with the transfer functions to provide an estimate of a minimum value of pCO_2 for the Falkland dataset. Depending on the transfer equation used, the upper error limit of our fossil SI gives pCO_2 estimates of 1300 ppmV (Beerling and Royer, 2002b, eqn. 2b) or 1430 ppmV (eqn. in Royer, 2003), which represent minimum values unconstrained at the upper limit.

However, the training set data for modern *Ginkgo* based on herbarium material and experimental studies (Royer et al., 2001; Beerling and Royer, 2002b; Royer, 2003) show a discontinuity at CO_2 above ~350 ppmV (SI < ~8) where the slope of the graph expressing the relationship quickly flattens out, suggesting a ceiling to response to elevated levels of pCO_2 (Fig. 3.12). For this reason, Royer et al. (2001) suggested that pCO_2 estimates from *Ginkgo* >400 ppmV should be treated as "semi-quantitative", and Beerling and Royer (2002b) suggested that the non-linear response of stomatal frequency of *Ginkgo* is likely to limit the usefulness of this proxy measure at elevated pCO_2 (>600 ppmV). When SI values fall within the asymptote of the calibration set curve, a very small difference in SI has a large impact on the pCO_2 estimate and error ranges are large.

This point has recently been discussed and illustrated by Beerling et al. (2009) through the construction of probability density functions for a range of CO_2 estimates based on stomatal frequency of *Ginkgo*. They note that although the declining sensitivity of stomatal frequency to pCO_2 at elevated levels (i.e. the "ceiling response") is often highlighted (e.g. Royer et al., 2001; Beerling and Royer, 2002b), less attention has been paid to the issue of increasing uncertainty at higher pCO_2. Although the new method of Beerling and colleagues provides better quantification of this uncertainty, nevertheless, the limitations of the training data at the higher end of the pCO_2 scale still suggest that stomatal frequency of *Ginkgo* at greatly elevated pCO_2 is limited to providing a semi-quantitative indication of the magnitude of pCO_2. That is, "significantly higher-than-modern" pCO_2 when fossil SI is markedly lower than modern *Ginkgo* (SI < 8), as is the case for the Falkland dataset. As demonstrated by Beerling et al. (2009), SI values between 7 and 8 will have envelopes of uncertainty that encompass virtually the entire range of the training set data (i.e. ~300–800 ppmV).

The use of the stomatal ratio method provides an additional semi-quantitative assessment of pCO_2 based on stomatal frequency. This method relates the SI of a nearest living equivalent (based on morphology, taxonomy, and/or ecology) to the SI of a fossil plant (Chaloner and McElwain, 1997; McElwain, 1998). The stomatal ratio (SR) value is then translated to a ratio of pCO_2 levels (RCO_2) by one of two standardizations: 1 SR=2RCO_2 (Carboniferous standardization) or 1SR=1RCO_2 (Recent standardization), relative to pre-industrial levels of CO_2 ~300 ppmV (McElwain, 1998). Using the SI value for the Falkland fossil *Ginkgo* of 5.8±0.4, the SR method (Recent standardization) suggests pCO_2 of 580±40 ppmV (with pre-industrial *Ginkgo* SI set at 11.33 and pCO_2 at 300 ppmV; Beerling and Royer, 2002b). Adjusting for paleoelevation of the site, estimated at ≥1.3 km (Smith et al., 2009), gives a minimum pCO_2 estimate of 680±50 ppmV from the SR method.

Although the SR method was not designed for use with SD values, SD and SI values tend to show similar trends with respect to pCO_2 (Royer, 2001), and the SD values are, in our view, more likely to be accurately determined in the case of *Ginkgo,* due to the facility with which the stomata can be identified relative to epidermal cells. A cross-check using SD values in the SR equation with SD of pre-industrial level *Ginkgo* set at 134 mm^{-2} (SD of *G. biloba* from 1924 herbarium sheet, when pCO_2 ~300 ppmV; Chen et al., 2001) provides a broadly consistent result, with pCO_2 estimated at 670±40 ppmV, adjusted to 780±50 ppmV to account for elevation.

The SR method assumes a linear relationship between stomatal frequency and pCO_2, in contrast to the non-linear relationship demonstrated by the training sets for *Ginkgo*. Therefore, results from the SR method should provide a more conservative estimate of minimum values compared to estimates derived from training set transfer functions. Taking both methods into account, based on the Falkland dataset pCO_2 in the EECO is interpreted as >600 ppmV (>2× modern pre-industrial values).

3.5.1 Atmospheric pCO_2 during the early Paleogene

The results of the present study, suggesting significantly higher-than-modern levels of pCO_2 (>600 ppmV) during the Early Eocene Climatic Optimum, overlap at the upper end of the scale of the revised estimates for the early Paleogene from the *Ginkgo*-based data of Royer and colleagues (Royer et al., 2001; Royer, 2003), as reanalyzed by Beerling et al. (2009). The present estimate is lower than those suggested by Retallack (2001) for the early Paleogene from *Ginkgo* stomatal frequency; however, as discussed above, this discrepancy is due in part to the transfer function employed. The absolute values of *Ginkgo* fossil SI reported by Retallack (2001) fit quite well with results from the present study (Fig. 3.9). Both McElwain (1998) and Kürschner et al. (2001) found significantly lower stomatal frequencies (both density and index) in early-middle Eocene fossil angiosperm leaves compared to modern counterparts, indicating elevated pCO_2. McElwain (1998) used two genera of fossil Lauraceae, *Lindera* and *Litsea*, from localities in southern England dated 44–50 Ma and estimated pCO_2 at 1.4–3.0 times preindustrial levels. Kürschner et al. (2001) used *Ternstroemites* (Theaceae) leaves from the lower middle Eocene Claiborne Group of Kentucky, and found pCO_2 moderately enriched at 450–500 ppmV (considered minimum values). Greenwood et al. (2003) reported an early Eocene pCO_2 estimate of ~340–350 ppmV based on a transfer function derived from an herbarium calibration from the dicot *Neolitsea dealbata* (R. Br.) Merr., but applied this to a fossil species of *Litsea*, contrary to the recommendation of applying transfer function calibrations to single species, potentially explaining the relatively low pCO_2 values provided.

Results from studies utilizing stomatal frequency as a proxy measure of paleo- pCO_2 can also be compared to the estimates produced by a range of geochemical proxies for the early Paleogene (for review see Royer, 2003, 2006). Pearson and Palmer (2000) used boron isotopes from foraminifera to determine the pH of seawater and estimate pCO_2 over the past 60 million years. Their estimates oscillated widely for the early Paleogene, between ~600 and 3500 ppmV during the early Eocene. Demicco et al. (2003) revised this record based on new values for seawater ionic composition and changes in the mineralogy of marine carbonates, and obtained generally lower pCO_2 estimates for the early Paleogene (~60–40 Ma) of 100–300 ppmV with oscillations up to 1200–2500 ppmV. Notably, a spike in pCO_2 (1200–2500 ppmV) is suggested from their data ca. 52 Ma, coincident with the Early Eocene Climatic Optimum. Based on the precipitation of nahcolite in evaporite deposits of the Green River Formation, Lowenstein and

Demicco (2006) suggested minimum pCO_2 levels for the early Eocene (51.3–49.6 Ma) of 1125 ppmV.

Analyses of stable carbon isotopes from paleosols have provided a wide range of pCO_2 estimates for the early Paleogene, from <350 ppmV (Koch et al., 1992) to <700 ppmV (Cerling, 1991; Sinha and Stott, 1994) to higher estimates of ~600–2000 ppmV (Royer et al., 2001). Yapp (2004) suggested pCO_2 during the Early Eocene Climatic Optimum (ca. 52 Ma) was ~2700 ppmV based on isotopic analysis of pedogenic geothite. Fletcher et al. (2008) analyzed stable carbon isotopes from bryophyte (liverwort) fossils, and found values in the early Paleogene of ~680 ppmV, although one sample from the early Eocene (48.6–55.8 Ma) yielded extremely high values (2300–4740 ppmV) which the authors regarded with some caution and attributed to a decreased sensitivity of the bryophyte proxy at elevated pCO_2. Geochemical modeling of the global carbon cycle has suggested pCO_2 values for the early Eocene (ca. 50 Ma) of ~1000 ppmV (Berner and Kothavala, 2001), while regional modeling of climate and pCO_2 in western North America for the early Eocene (50-56 Ma) has suggested minimum levels of 2240 ppmV (Thrasher and Sloan, 2009). From this summary, it is clear that the early Eocene presents a particular challenge for reconstructing paleo-pCO_2 levels; some but not all proxies suggest a high pCO_2 excursion coincident with the EECO.

3.5.2 Coupled changes in pCO_2 and temperature during the EECO

Trends in stomatal frequency (and by inference pCO_2) can be compared with estimates of mean annual temperature (MAT) for the three units at the Falkland site derived from leaf margin analysis, a technique based on the observed positive correlation between the proportion of woody dicot leaf taxa with entire (non-toothed) margins and MAT in modern environments (Wilf, 1997). Leaf margin analysis on plant macrofossils collected from the Falkland locality shows a trend towards declining MAT over time with Unit 1 giving the warmest signal of the three units (Fig. 3.11). Unit 1 also shows the lowest stomatal frequency values, and by extension highest pCO_2. The significance of the difference between the three units is not clear, as errors overlap and Unit 1 does not have the preferred minimum number of 5 specimens; however, both measures of stomatal frequency show the same trend, with Unit 1 displaying the lowest values. These results suggest that temperature and pCO_2 were coupled in the waning phase of the EECO hyperthermal, and that stomatal frequency values track changes over geologically short time periods.

3.5.3 Considerations on measures of stomatal frequency as a proxy for pCO_2

Stomatal index has been generally regarded as the preferred measure for studies of paleo-pCO_2. Stomatal density may be influenced by the degree of leaf cell expansion which, in turn, may be influenced by a number of environmental factors; in contrast, stomatal initiation (and hence SI) has been reported to be influenced primarily by levels of atmospheric CO_2 and plant genotype (Salisbury, 1927; McElwain and Chaloner, 1996; Royer, 2001; Lake et al., 2002). Nevertheless, if SI cannot be accurately determined due to ambiguity in cell boundaries, or if there is significant observer differences between studies, then this theoretical advantage may be lost in application. In addition, studies of natural variability in modern populations of *G. biloba* (Chen et al., 2001; Sun et al., 2003) found that SI may also be influenced by seasonal variation in leaf maturation, canopy position, and leaf area (in the case of small juvenile leaves), although the magnitude of this variability did not overprint the pCO_2 signal (Chen et al., 2001; Sun et al., 2003). Chen et al. (2001) found a significant difference in SD of long- and short-shoot leaves, but not in SI. Our examination of modern *G. biloba* leaves confirmed the significant difference in SD values for long- and short-shoot leaves. We also found a significant difference in SI between long- and short-shoot leaves using the acetate replica dataset, although this signal was not seen in the macerated cuticle dataset, suggesting that methods of preparation and analysis may compromise results. These findings suggest that SI is influenced by environmental, developmental, specimen-preparation, and observational influence.

To deal with the difference between stomatal frequency of long- and short-shoot leaves, ideally both the training sets and the fossil specimens should represent either: a) an even mix of long- and short-shoot leaves to give an average value; or b) represent only long- or short-shoot leaf morphotypes. Unless the fossil leaves are preserved in attachment, which is highly unlikely, it is not possible to determine the status of an individual leaf as being from a long or short shoot, notwithstanding the observation that there is a tendency towards greater dissection of long-shoot leaves in modern *G. biloba* (Critchfield, 1970; Fig. 3.2). As with short-shoot leaves, the earliest-formed long-shoot leaves may be established within overwintering buds, and tend to develop similarly fan-shaped morphology, whereas later-formed long-shoot leaves tend to greater dissection. While this does provide some basis upon which to select fossil specimens for analysis, it is far from a definitive characteristic.

In mature trees, however, short shoots greatly outnumber long shoots, and produce the majority of foliage (Critchfield, 1970). As a result, random samples of many leaves, either from the fossil record or in development of modern training sets, will be dominated by short-shoot leaf SI/SD signals. Where sample size is small, and particularly where a single leaf has been sampled from the fossil record, the probability that this may represent long-shoot leaf stomatal frequency emerges as a concern. Our data from short- and long-shoot leaves from modern *Ginkgo biloba* (Table 3.1) reveal a mean value of SI for long-shoot leaves of up to 2.4 greater than for short-shoot leaves, a difference that would dramatically alter estimation of $p\mathrm{CO_2}$. In the case of the present study, we selected only those fossil specimens that represented the fan-shaped morphology in an attempt to minimize long-shoot bias, making it very likely that our sample of 14 leaves is giving a short-shoot SI/SD signal. The status of the leaves in the modern calibration training set as short or long shoot was not recorded, although the dataset likely represents a mix of these leaf types (D. Royer, pers. comm. 2010). Therefore, our analysis rests on the assumption that modern training sets and the Falkland dataset are dominated by the short-shoot signal.

Although most attention has been devoted to developing transfer functions based on SI, we argue here that it would be beneficial to have corresponding functions developed using SD, at least in the case of *Ginkgo*. Unless the prepared cuticle or cuticle impression is of exceptionally good quality, there is a degree of ambiguity in identifying epidermal cell boundaries due the nature of the epidermal cell architecture in *Ginkgo*. It should be noted that other taxa might not suffer from the same difficulty as *Ginkgo*, depending on their particular cellular architecture and cuticular features. In order to calculate SI, the outlines of epidermal cells (in addition to the stomatal complexes) must be clear, as noted by Chaloner and McElwain (1997). This is difficult to achieve with fossil material, and even modern material of *G. biloba* is problematic in this respect. McElwain and Chaloner (1996; McElwain, 1998) only published SD values for fossil and modern *Ginkgo* for this reason. In contrast to the epidermal cells, stomata are generally easily identified and counted in both fossil and modern specimens. Royer (2001) concluded from his review of stomatal frequency studies that SI and SD were equally likely to vary inversely with CO_2. The SD and SI values reported here are generally consistent in trend and scale of difference between modern and fossil specimens, but we believe that the SD values are more accurate, reliable, and replicable (i.e., result in increased precision). In addition, SD is more meaningful in physiological terms than SI, as the former can be equated with stomatal conductance (and thereby water use efficiency) since it confers information on stomatal pore capacity (Beerling et al., 1998).

3.6 CONCLUSIONS

Estimates of pCO_2 for the EECO presented in this study support the higher-than-modern range of estimates suggested by other proxy measures, although it is not possible to constrain the upper limit based on *Ginkgo* stomatal frequency. While minimum values suggested by transfer functions as applied to the Falkland specimens indicate pCO_2 >1300 ppmV, nevertheless, a more conservative interpretation, recognizing both the limitation in response of *Ginkgo* to elevated pCO_2, and uncertainties involved in measuring SI from *Ginkgo* cuticle, suggests that the estimate of pCO_2 should be expressed as >600 ppmV. This latter estimate is supported by semi-quantitative results using the SR method for SI, and an adjusted SR method for SD values. These results contrast with earlier studies of stomatal analysis of *Ginkgo* that suggested near modern-day levels in the early Eocene (Royer et al., 2001; Royer, 2003), although these earlier studies did not include samples from the EECO hyperthermal, and reported estimates have since been revised upwards by 150–250 ppmV (Beerling et al., 2009) so that their upper range now overlaps with our results. Also presented here is evidence of correlated trends in temperature and pCO_2 during the waning phase of the EECO, based on correlated inverse values for stomatal frequency and MAT in three units of the Falkland site.

Natural variability in stomatal frequency of *G. biloba* as assessed in this study suggests that care should be taken to distinguish between the values of long- and short-shoot leaves in calibration of training sets of modern leaves and, as far as possible, in fossil specimens. As the majority of leaves on a tree are borne on short shoots, large sample sizes are likely to represent a short-shoot SI/SD signal. Small sample size, particularly where a single leaf is utilized, introduces significant potential for long-shoot bias which could dramatically alter estimation of pCO_2.

The SI values of *Ginkgo*, whether modern or fossil, should be treated with some caution, due to the likelihood of observer error in counting epidermal cells, as anticlinal walls are often obscured by papillae. Reporting SD values, in addition to SI, provides a cross-check on the accuracy of the SI values. SD values appear to be less prone to observer error and therefore likely to be more consistent across studies and methodologies.

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Table 3.1. Summary of stomatal frequencies for modern and fossil *Ginkgo*

Sample	Stomatal Density (mm^{-2})						Stomatal Index (%)					
	n	N	*x*	s	se	95% CI	n	N	*x*	s	s.e.	95% CI
Modern *Ginkgo biloba*												
Acetate peel dataset	25	75	**97**	22	3	5	25	75	**9.5**	2.1	0.2	0.5
Macerated cuticle dataset	30	90	**95**	23	2	5	25	57	**10.7**	1.8	0.2	0.5
Long-shoot leaves acetate peels	12	36	**107**	21	4	7	12	36	**10.7**	1.8	0.3	0.6
Long-shoot leaves macerated cuticle	15	45	**105**	24	4	7	12	31	**11.3**	1.7	0.3	0.6
Short-shoot leaves acetate peels	13	39	**87**	18	3	6	13	39	**8.3**	1.6	0.3	0.5
Short-shoot leaves macerated cuticle	15	45	**85**	17	3	5	12	26	**10.5**	1.8	0.4	0.7
Fossil *Ginkgo adiantoides*												
All specimens	14	42	**60**	12	2	4	14	42	**5.8**	1.5	0.2	0.4
Unit 1	4	12	**55**	14	4	8	4	12	**5.1**	1.3	0.4	0.7
Unit 2	5	15	**59**	10	3	5	5	15	**5.8**	1.0	0.3	0.5
Unit 3	5	15	**64**	11	3	6	5	15	**6.4**	1.7	0.4	0.9

Note: n, number of leaves; N, number of counts; *x*, mean; s, standard deviation; s.e., standard error of mean; 95% CI, 95% confidence interval. Numbers in bold are mean values. Data was rounded at the last step of calculations to one decimal place for SI, and error was calculated on raw values in all cases.

Table 3.2. Comparison of published stomatal frequencies for modern *Ginkgo biloba*.

Reference	**Stomatal Index**	**Stomatal Density (mm^{-2})**
This study: acetate replicas	9.5	97
macerated cuticles	10.7	95
Royer (2003)	8.1[a]	n/a
Sun et al. (2003)	9.1–9.9[b]	78–98[b,c]
Chen et al. (2001)	9.3	97.7
Beerling et al. (1998)	8.6[b]	77[b]
McElwain and Chaloner (1996)	n/a	84.8

[a]Average of SI values for samples dating 1990–2000.
[b]Values estimated from graphs
[c]SD values for sun leaves typically between ~95–98 mm^{-2} as estimated from graphs

Fig. 3.1. Map showing location of the Falkland fossil site, and select Okanagan Highlands localities (Republic, Princeton, Quilchena, McAbee, Horsefly). A) Outline map of Canada, with GIS data provided by The Atlas of Canada (Department of Natural Resources Canada). B) Detail of portion of British Columbia, Canada and Washington, USA. World shaded relief map data provided by ESRI ArcGIS Online and data partners.

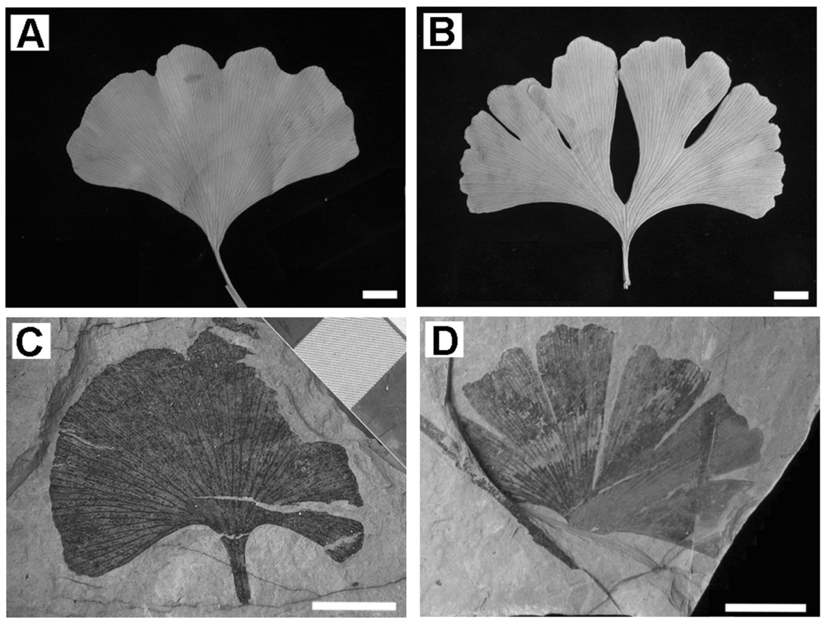

Fig. 3.2. Heterophylly in extant *Ginkgo biloba* (A and B) and fossil *Ginkgo adiantoides* (C and D). A) Typical fan-shaped morphology of extant short-shoot leaf. B) Long-shoot extant leaf showing tendency to greater dissection. C) Fan-shaped morphology in fossil specimen RYS07-0067. D) Dissected morphology in fossil specimen RYS06-0043.
Scale bar in A–D = 1 cm.

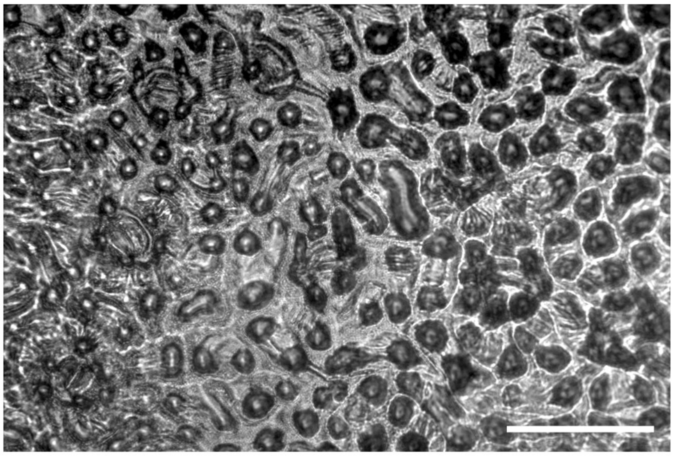

Fig. 3.3. Light microphotograph of modern *Ginkgo biloba* abaxial cuticle, acetate replica. Specimen 2006-3-2. Scale bar = 100 μm.

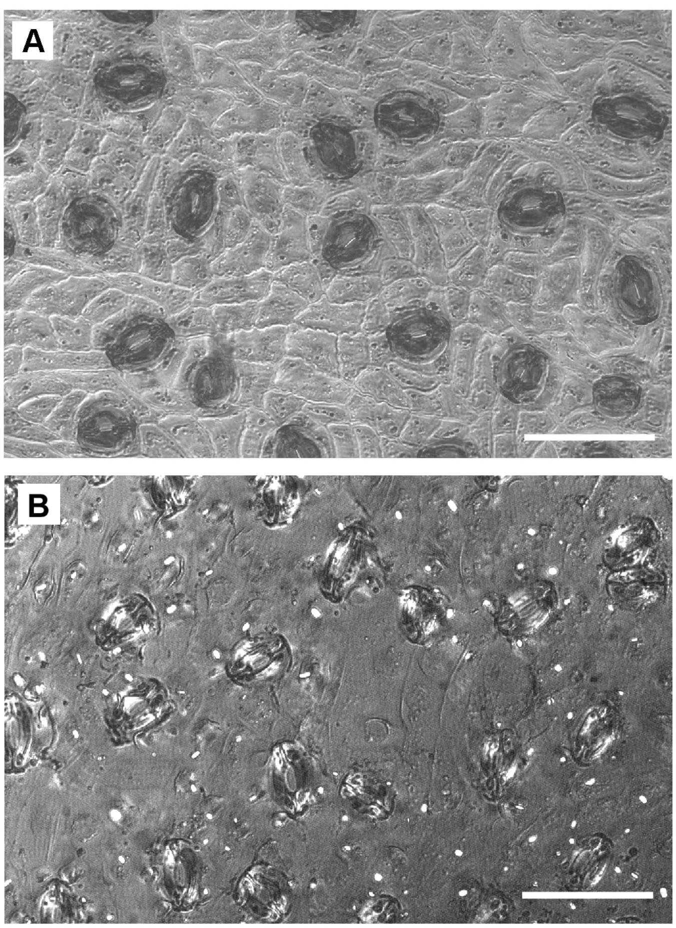

Fig. 3.4. Light microphotographs of modern *Ginkgo biloba* abaxial cleared cuticle. A) Specimen 2008-01 (best example from methodological trials). B) Specimen 2008-10 (typical example from methodological trials). Scale bar = 100 μm.

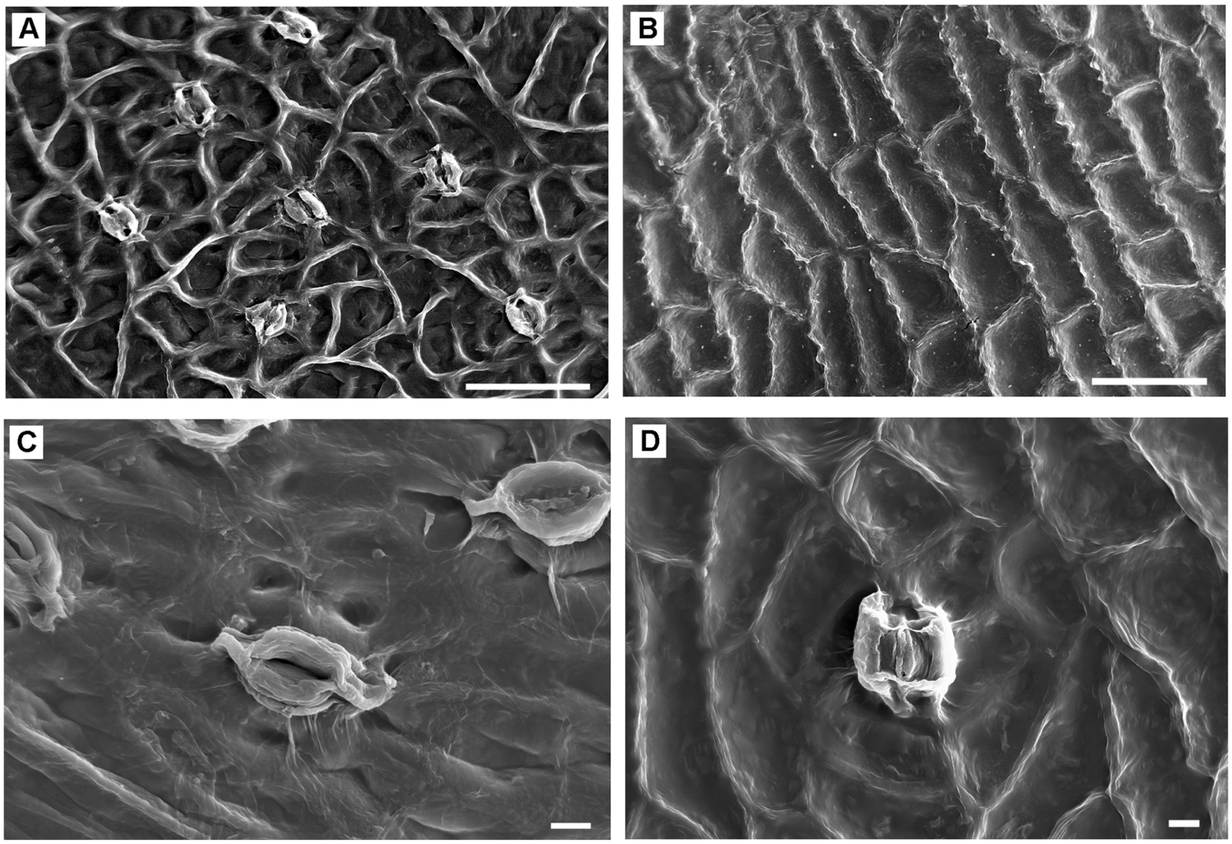

Fig. 3.5. Scanning electron microphotographs of modern *Ginkgo biloba* cuticle. A & B are from a short-shoot shade leaf; C & D are from a long-shoot sun leaf.
A) Abaxial cuticle, inner surface, showing stomata and epidermal cells.
B) Adaxial cuticle, inner surface, showing epidermal cells with undulate anticlinal walls.
C) Abaxial cuticle, inner surface, detail of stomata showing cavities of papillate subsidiary cells.
D) Adaxial cuticle, inner surface, detail of rare stomata on adaxial surface.
Scale bar in A & B = 100 μm; C & D = 10 μm.

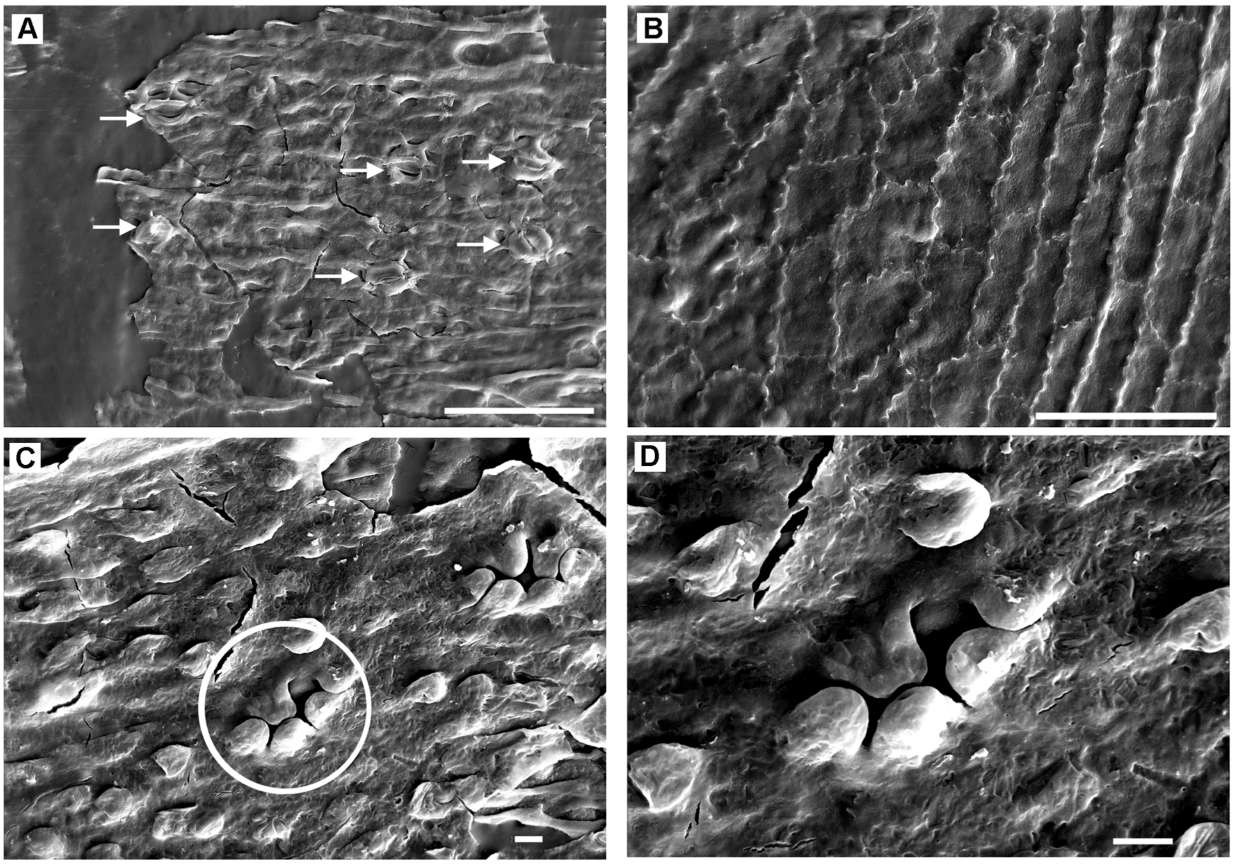

Fig. 3.6. Scanning electron microphotographs of fossil *Ginkgo adiantoides* cuticle. Specimen RYS06-0676 from Falkland, BC. A) Abaxial cuticle, inner surface, showing stomata (arrows) and epidermal cells. B) Adaxial (non-stomatal bearing) cuticle, inner surface, showing epidermal cells with undulate anticlinal walls, polygonal cells in intercostal area and rectangular-elongate cells over veins (right side of image). C) Abaxial cuticle, outer surface, showing stomata and papillate epidermal cells (one of two visible stomata circled). D) Detail of C, showing five papillae occluding the stomatal pore.
Scale bar in A & B = 100 µm; C & D = 10 µm.

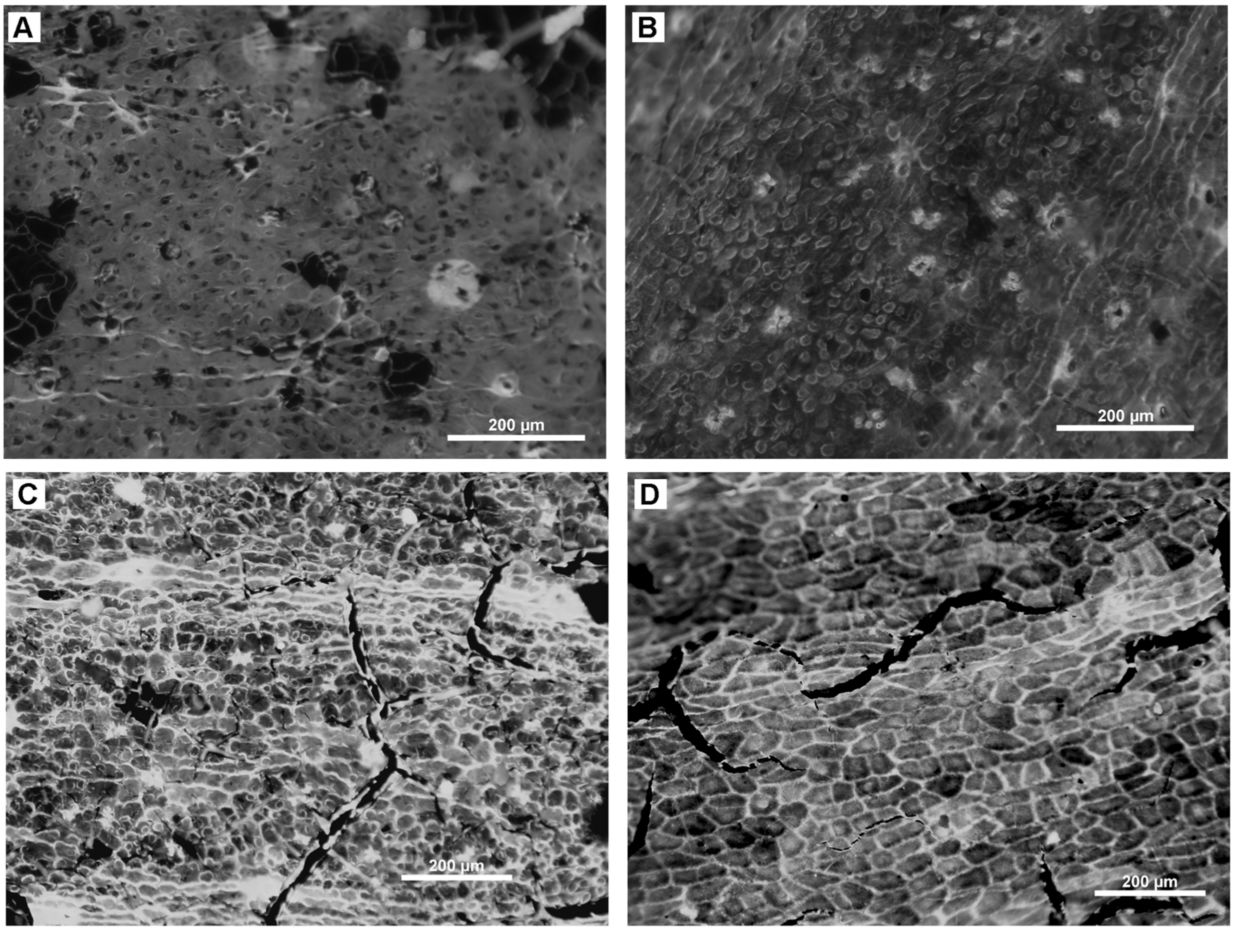

Fig. 3.7. Epifluorescence photomicrographs of fossil *Ginkgo adiantoides* cuticle. Stomata are identifiable by their strongly fluorescing surrounding cells. A) Specimen RYS07-0480, abaxial cuticle, inner surface, showing stomata. B) Specimen RYS07-0480, abaxial cuticle, outer surface, showing stomata and papillate epidermal cells. C) Specimen RYS0896, abaxial cuticle, inner surface showing stomata with strongly fluorescing surrounding cells. D) Specimen RYS06-0949, adaxial cuticle, showing epidermal cells. Scale bars = 200 µm.

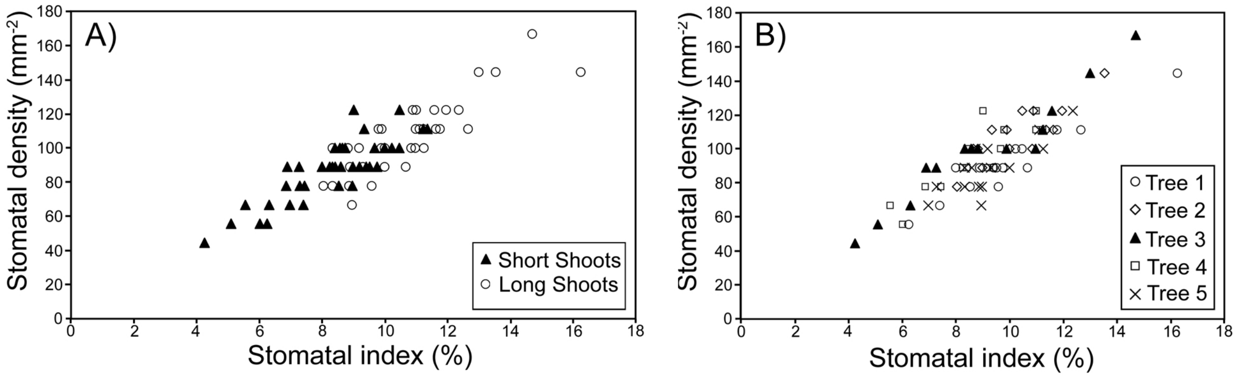

Fig. 3.8. Scatterplot showing SD and SI values for modern *Ginkgo biloba* acetate peel dataset. Each point represents a single field-of-view count. A) Data separated by long- and short-shoot leaf status. B) Data separated by individual tree.

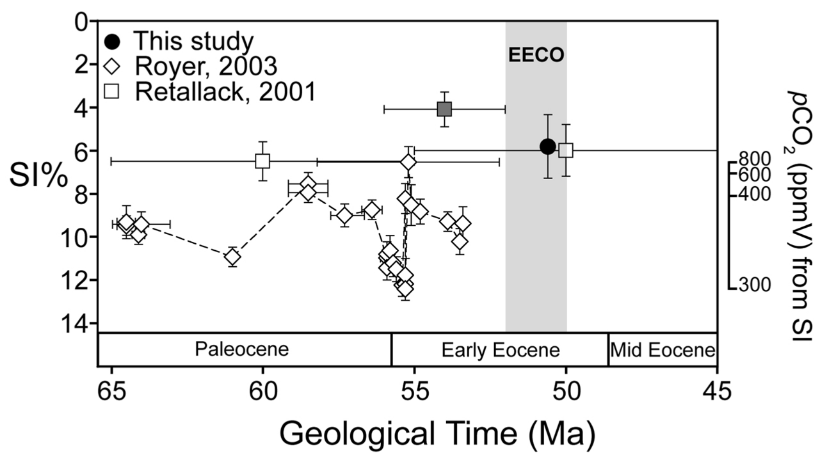

Fig. 3.9. Published SI values for early Paleogene *Ginkgo*, with results from this study. Error bars for SI represent 1 standard deviation to provide consistency across studies. Royer (2003) incorporates data from Royer et al. (2001) and Beerling et al. (2002), with error ranges for SI (standard deviations) given in Beerling et al. (2009) and error ranges for dates given in Appendix A of Royer (2006). Axis showing SI values is reversed to correlate with pCO$_2$. pCO$_2$ scale from Royer (2003). The shaded data point from Retallack (2001) indicates the sample based on < 5 leaf fragments (see note in text).

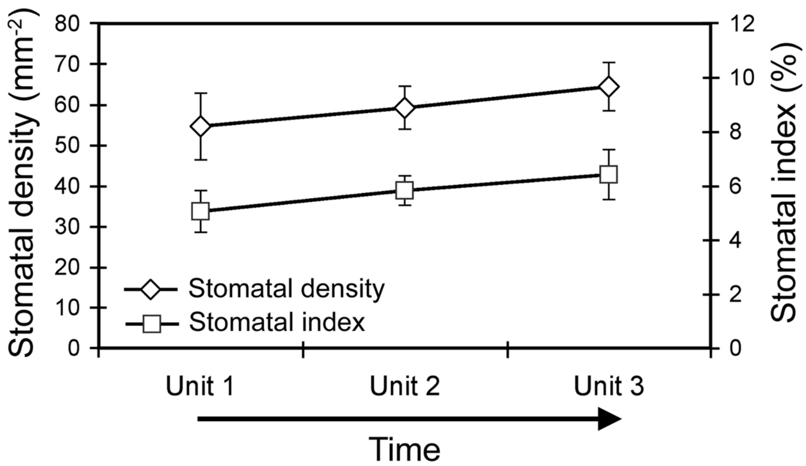

Fig. 3.10. Stomatal frequency for *Ginkgo adiantoides* by unit at the Falkland site. Unit 3 is the youngest (upper) unit. Errors are 95% confidence intervals.

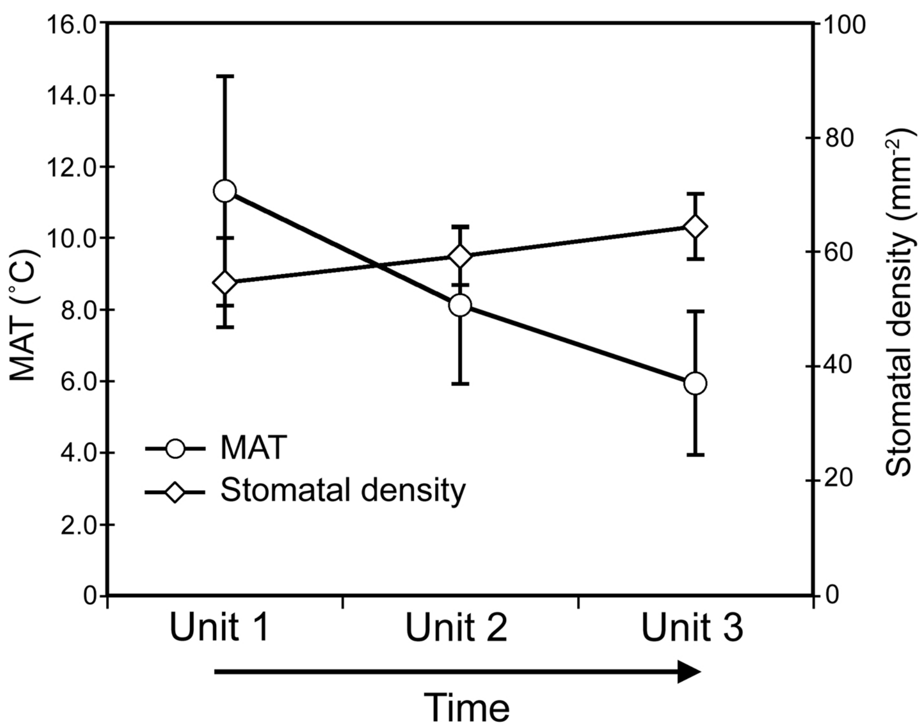

Fig. 3.11. Trends in stomatal density and mean annual temperature (MAT) over time at the Falkland site. MAT for the three units calculated via leaf margin analysis using the equation of Kowalski and Dilcher (2003) where MAT=2.223+(36.3×P) and P is the proportion of woody dicot taxa with entire margins. Unit 1 P = 0.25, Unit 2 P = 0.16, Unit 3 P = 0.10. Errors for stomatal density are 95% confidence intervals; errors for MAT are the binomial sampling error as per Wilf (1997).

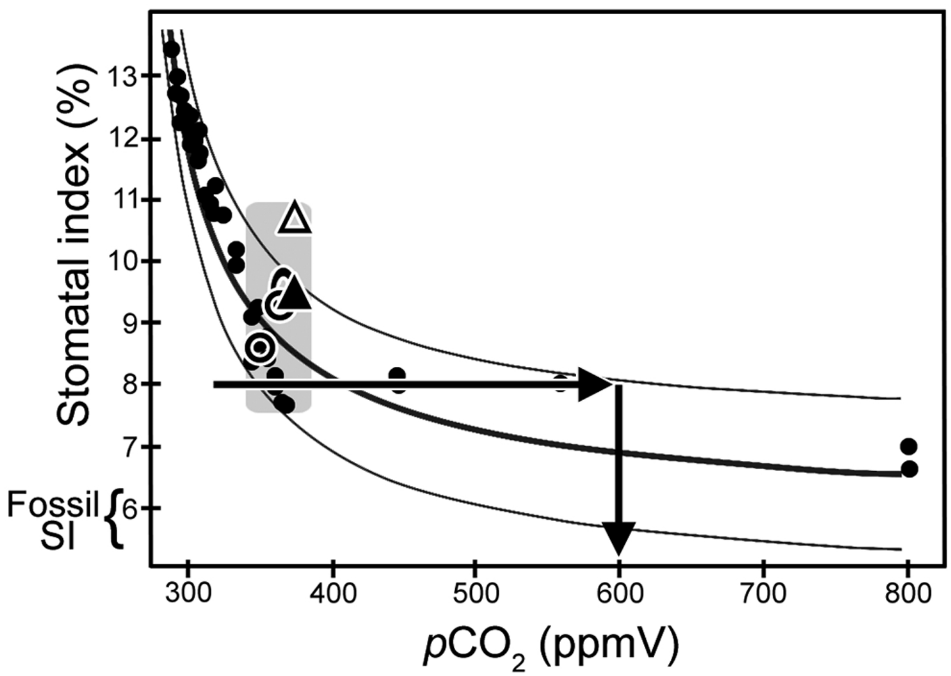

Fig. 3.12. Training set of modern *Ginkgo* data expressing the relationship between stomatal index and pCO_2, redrawn from Figure 2A in Royer (2003). Closed circles represent the original training dataset in Royer (2003) including herbarium, modern, and experimental data (experimental trials with CO_2 exposure >1 growing season); triangles are the modern *Ginkgo* data from this study (closed triangle for acetate peel data set, open triangle for cleared cuticle data set); open circles are published SI values for modern *Ginkgo* (data from Table 2); the shaded area represents a general range of modern (1990 to present) *Ginkgo biloba* SI from the published literature (Table 3.2). Arrows illustrate that for SI < ~ 8 estimates of pCO_2 become unconstrained (i.e. at elevated pCO_2 > ~600 ppmV).

4. EARLY EOCENE PLANT DIVERSITY AND DYNAMICS IN THE FALKLAND FLORA, OKANAGAN HIGHLANDS, BRITISH COLUMBIA, CANADA[3]

Abstract: The early Eocene fossil localities of the Okanagan Highlands in British Columbia, Canada, and Washington State, USA, have yielded diverse and well-preserved plant and insect fossil assemblages. These fossil sites span the Early Eocene Climatic Optimum, and reflect mild but equable climates (mean annual temperature <15°C, cold month mean temperature >0°C). Here, we characterize the plant community and assess changes over time in plant diversity at one of the lesser-studied Okanagan Highlands localities near Falkland, British Columbia. Macrofossil collections were obtained from Falkland using an unbiased census approach with systematic sampling through three informal units in the exposed outcrop yielding 1843 specimens from census quarries, used here to assess trends over time within the site and to compare diversity to other early Eocene sites sampled in a similar manner. Rarefaction analysis shows Falkland as having diversity comparable to that of the contemporaneous and hyper-diverse Laguna del Hunco site in Argentina, and higher than that of Republic, Washington and McAbee, BC at comparable sample sizes. These data are consistent with an emerging understanding of high diversity within these early Eocene forest communities associated with mild but equable climates. Within the Falkland site, the plant community retains a foundation of common taxa through all three units, including *Metasequoia*, *Ginkgo*, and *Alnus*; however, the diversity of dicot angiosperms is higher in the upper unit than lower in the sequence. Ordination of quarries using non-metric multidimensional scaling shows a clustering of quarries by unit, confirming the presence of a distinct plant community in the upper unit. Patterns in plant diversity are assessed within a context of changing climate and disturbance regime over time at the Falkland site.

4.1 INTRODUCTION

The early Eocene fossil localities of the Okanagan Highlands in British Columbia, Canada, and Washington State, USA, have received growing attention in recent years as sources of diverse and well-preserved plant and insect fossil assemblages. These sites, formed in similar depositional environments within a relatively short period of time of ~3 million years, provide

[3] This chapter in written in GSA style. Coauthors are James F. Basinger (University of Saskatchewan) and David R. Greenwood (Brandon University).

comparative data with which to explore variation in biotic communities across time and space (Archibald and Greenwood, 2005). The early Eocene was the interval of peak warmth in the Cenozoic (Zachos et al., 2001, 2008), and the Okanagan Highlands span the acme of this warmth at the Early Eocene Climatic Optimum (EECO), ca. 50–53 Ma. The fossil record indicates that the early Eocene was characterized by generally warm (i.e., MAT ≥15°C) and equable climates in North America (Wing et al., 1991; Wing and Greenwood, 1993; Greenwood and Wing, 1995). The Okanagan Highlands represent relatively cool upland environments (i.e. MAT <15°C) in the Eocene landscape of northwestern North America (Greenwood et al., 2005; Smith et al., 2009). These cool microclimates provided niches for the diversification of many temperate plant families (Wehr, 1998; DeVore et al., 2005; DeVore and Pigg, 2007).

Previous work has suggested that Republic, Washington (the southern-most Okanagan Highlands locality) yields the most diverse fossil flora of western North American Eocene sites (Johnson, 1996), although based on rarefaction it is less diverse than southern hemisphere early Eocene Laguna del Hunco and Río Pichileufú sites of Argentina that offer good comparisons with the western North American sites due to similarity in collection methods, mid-latitude position, and approximately coeval dates (Wilf et al., 2003, 2005). Analysis using rarefaction of the insect fauna of the Okanagan Highlands has demonstrated tropical-style diversity for the McAbee assemblage, despite the mid-latitude position and relatively cool microthermal upland climate (Archibald and Farrell, 2003; Archibald et al., 2010). Archibald et al. (2010) also provided a preliminary rarefaction curve for the McAbee leaf flora, showing comparable diversity to that of Republic, although their McAbee sample was small (<150 specimens).

In contrast to these studies showing high early Eocene diversity at mid-latitudes, a study of vegetation diversity in the early Paleogene based on pollen demonstrated a strong latitudinal gradient in diversity between sites in the US Gulf Coast and the Canadian Arctic, with decreasing diversity with increasing latitude even more pronounced than in the modern world (Harrington, 2004). However, the Paleogene samples analyzed by Harrington (2004) were derived from a limited number of localities and environments (mostly swamp coal facies for the Arctic sites) and may therefore reflect local landscape features rather than geographic patterns. Studies of fossil macrofloras representing a range of environments in the Denver Basin have demonstrated considerable diversity gradients within regional frameworks, influenced by local factors such as topography and precipitation (Johnson et al., 2003), suggesting caution in generalizing results from a limited number of localities across broad regions or continents. Across the Okanagan Highlands series of fossil sites there is an opportunity to assess diversity patterns within a well defined regional context (e.g., Greenwood et al., 2005; Archibald et al., 2010).

Trace fossil evidence of plant-insect interactions has been assessed in the Green River, Great Divide, and Washakie basins of southwestern USA (Wilf and Labandeira, 1999; Wilf et al., 2001). These studies show high diversity of insect feeding types in the early Eocene, coincident with increased temperatures and plant diversity, relative to the Paleocene (Wilf and Labandeira, 1999; Wilf et al., 2001). The Falkland flora demonstrates extensive evidence of insect activity, including trace fossils of margin feeding, galling, oviposition, and leaf mining activity (for example, see morphotypes FL011, FL060, and FL121 in Appendix A). Although not considered as part of this study, future work on the insect trace fossils of the Falkland flora could yield complementary information on co-evolution of plant and insect taxa and diversity of insect feeding patterns in the early Eocene.

Here, we characterize the plant community of a single site and assess changes over time in diversity and structure of the fossil flora at one of the lesser-studied Okanagan Highlands localities near the town of Falkland in British Columbia. Macrofossil collections were obtained from the Falkland locality using an unbiased census approach, with systematic sampling through the exposed outcrop. The site stratigraphy preserves evidence of periodic environmental disturbance in the form of volcanic activity and change in lake levels (Smith et al., 2009), and paleoclimate estimates based on the fossil flora indicate declining mean annual temperatures over time (Smith et al., 2010). The fossil flora can be analyzed within this environmental context to consider plant community response to disturbance and climatic change. The volcanically active landscape of British Columbia in the early Eocene provides an important environmental context to the analysis of plant diversity and dynamics, both in terms of shaping the disturbance regime and potentially modifying nutrient influx (Jolley et al., 2008). This analysis adds to a growing compilation of comparative paleobotanical data from the northern and southern hemispheres (e.g. Wilf, 2000; Passmore et al., 2002; Wilf et al., 2003, 2005; Iglesias et al., 2007; Wing et al., 2009), and complementary data based on both insect trace and body fossils (Wilf and Labandeira, 1999; Wilf et al., 2001; Archibald et al., 2010) that is developing a more dynamic picture of biotic communities in the early Paleogene.

4.2 MATERIALS AND METHODS

Plant macrofossils were collected from the early Eocene Falkland locality in south-central British Columbia, Canada (50.516°N, 119.628°W, elevation 1369 m.a.s.l.). Falkland is part of a series of correlatives sites in British Columbia and Washington State known collectively as the Okanagan Highlands (Fig. 4.1) (Greenwood et al., 2005). The site has been dated to 50.61±0.16 Ma, using U-Pb analysis of zircons from volcanic ash layers interleaving the fossil beds, placing it in the waning phase of the Early Eocene Climatic Optimum (Greenwood et al, 2005; Moss et al., 2005). Macrofossils were collected using an unbiased census approach, whereby all specimens encountered in systematically sampled quarries were collected and/or recorded. Two continuous vertical sections of ~2.5 m each were sampled in this manner. Based on site lithology and volcanic ash layers that could be traced laterally across the outcrop, the sections were divided into three informal units (see Smith et al., 2009). In addition, eight quarries of various sizes were census-collected across the outcrop. Numerous specimens were also collected from scree (without stratigraphic context), or from spot localities *in situ* in the outcrop in a selective (non-census) manner with the goal of improving the quality of the reference collection.

As a first step towards understanding the Falkland fossil flora, specimens were sorted into discrete morphotypes, informal taxonomic categories based on aspects of morphology or leaf architecture (Johnson and Ellis, 2002; Peppe et al., 2008). For dicotyledonous leaves, the approach and terminology outlined in the *Manual of Leaf Architecture* (Ellis et al., 2009) was followed, utilizing database and spreadsheet resources developed by the Leaf Architecture Working Group (see Appendix A). Subsequently, the taxonomic literature was investigated and morphotypes were assigned to formal taxonomic categories where possible.

Census tally and other quantitative data, as well as qualitative data derived from the macrofossil collection were divided into datasets of increasingly restricted criteria, suitable for the various types of analyses considered here (Table 4.1). For example, for qualitative description of the plant communities at the Falkland site, the full dataset, including both census and biased collection specimens, are considered. For quantitative analysis of trends in diversity, only census-sampled material is utilized. These datasets are defined in Table 4.1. Datasets A and B (i) include those specimens that were assigned to a "general" morphotype category due to a lack of taxonomically diagnostic features, poor preservation, or incompleteness. The general morphotype categories are: FL99 (toothed dicot foliage – general), FL990 (entire-margined dicot foliage – general), FL999 (conifer foliage – general), FL9999 (monocot foliage – general) or FL9990 (reproductive or other plant part – general). These specimens remain in the full dataset as they provide information on relative abundance of angiosperm and gymnosperm specimens, and it may be possible at some point in the future to assign them to specific morphotypes. Datasets B (ii), C and D exclude these general morphotypes as they undoubtedly lump multiple taxa and would therefore skew an analysis of trends in diversity.

A discussion of the major taxonomic groups present at the Falkland site is provided below, and a record of all morphotypes, including those currently unassignable to formally recognized taxa, is provided in Appendix A. The purpose of this report is not primarily taxonomic; however, this overview and description of morphotypes will provide a solid foundation for future taxonomic work on the Falkland flora. Emphasis was placed on situating the Falkland flora within the recent taxonomic literature for the Okanagan Highlands, which has benefited from careful study of particular plant groups (e.g. Pigg et al., 2001; Pigg et al., 2003; DeVore et al., 2005; Radtke et al., 2005; Pigg et al., 2007) and efforts towards whole-plant reconstructions utilizing associated reproductive and vegetative material (e.g. Crane and Stockey, 1985; Schorn and Wehr, 1986; Crane and Stockey, 1987; Manchester and Dillhoff, 2004; Denk and Dillhoff, 2005). Much of the older taxonomic literature (early 20th century) is problematic due to poor illustration of type material and a tendency towards taxonomic splitting (Johnson et al., 2003), although this literature was consulted and possible assignments noted. The establishment of new species based on isolated leaf fossils was not considered at this time, to minimize proliferation of poorly defined taxa in the literature.

For quantitative analysis of trends in diversity and plant community composition, several statistical methods and diversity measures were explored. Alpha diversity in the three units is measured via simple species richness (number of taxa), along with the Shannon-Weiner index (H) calculated as:

$$H = \frac{(\log n! - \sum \log f_i!)}{n} \qquad (4.1)$$

where n is the sample size, and f_i is the number of observations in category i, in this case, the number of specimens in a particular morphotype (Zar, 1999, formula 4.23). The evenness of diversity (Pielou's J) was assessed by dividing the observed value of H by the maximum value of H:

$$J = \frac{H}{H_{\max}} \tag{4.2}$$

where $H_{\max}$ is the log of the number of categories (morphotypes) (Zar, 1999, formula 4.20). Perfect evenness would be represented by an equal number of specimens in all morphotypes, and therefore a J value of 1. In all calculations, a log base of 10 was used.

In order to assess trends within the site, as well as compare Falkland with other relevant early Eocene sites, rarefaction analysis and non-metric multidimensional scaling (NMDS, a multivariate ordination technique), were employed using the software package PAST version 1.99 (Hammer et al., 2001). Rarefaction provides a method for comparing the diversities of samples of different sizes (Raup, 1975). Given abundance data for taxa in the different samples, rarefaction determines the number of taxa you would expect in standardized sample sizes, up to the maximum number of specimens in each sample. The shape of the rarefaction curve is determined by the overall number of specimens and species, and by the evenness of the species abundance distribution (Raup, 1975). As noted by Tipper (1979) when comparing diversities at different sites (or from different studies) via rarefaction, it is important that samples are obtained by standardized techniques from similar habitats with similar taxonomic composition. Here, Dataset D (census dicots) from Falkland will be compared with other mid-latitude early to middle Eocene lacustrine deposits reported in the literature that have been sampled using an unbiased census approach. These sites include: McAbee, British Columbia (Archibald et al., 2010); Republic, Washington (Passmore et al., 2002; Wilf et al., 2003, 2005); locality DMNH 2484, Denver Basin, Colorado (Johnson et al., 2003); Green River, Bonanza River flora, Utah (Wilf et al., 2001, 2003); Laguna del Hunco, Argentina (Wilf et al., 2003, 2005) and Río Pichileufú, Argentina (Wilf et al., 2005). Details of depositional environment and paleoclimate for these sites are provided in Table 4.2.

Falkland, McAbee and Republic all represent early Eocene sites in the Okanagan Highlands, and compare well in terms of taxonomic composition and paleoclimate conditions

(Greenwood et al., 2005; Smith et al., 2009; Table 4.2). The preliminary rarefaction curve from McAbee was based on a very small sample (Greenwood et al., 2005; Archibald et al., 2010), whereas the data from Falkland represent systematic collecting over several field seasons. The Republic site has been collected intensively for many years (Wehr, 1995; Johnson, 1996; Wehr and Manchester, 1996; Pigg and Wehr, 2002; DeVore and Pigg, 2010); however, there is a discrete unbiased census collection housed at the Denver Museum of Natural History (DMNH) that was collected in a very similar manner to the present study, covering a 1.6 m unit at the site (Passmore et al., 2002). For the purposes of this analysis, only dicot leaf specimens from that collection are used (raw data provided by P. Wilf and K. Johnson). Laguna del Hunco and Río Pichileufú in Argentina also represent lacustrine deposits at mid-latitudes, although in a different hemisphere, and have warmer paleoclimate estimates with similar levels of precipitation compared to the Okanagan Highlands sites (Table 4.2). Only dicot leaf specimens from the four most productive quarries at the Laguna del Hunco site are considered here, along with the preliminary collections from the most productive quarry at Río Pichileufú (Wilf et al., 2003, 2005).

Wilf et al. (2003) also considered diversity on a whole site basis, comparing the combined Laguna del Hunco data (25 quarries) with other Eocene localities where several quarries have been sampled, including Florissant, Colorado; Chalk Bluffs, California; Puget Group, Washington; and sites dating to the EECO in Wyoming. They acknowledge that this practice may artificially increase diversity, due to the lumping of fossils from a variety of depositional settings, and time averaging to varying degrees, depending on the vertical and lateral extent of the areas sampled. A “whole-site” comparison with these other Eocene sites is not considered here for a variety of reasons. Florissant is a late Eocene site, while Chalk Bluffs, the Puget Group, and Wyoming localities represent a mosaic of depositional environments. The three units of the Falkland site reflect changes in the local environment and disturbance regime (Smith et al., 2009; this paper), but are all from a lacustrine deposit of limited vertical (~3 m) and lateral (~18 m) extent. The two stratigraphic sections which comprise the bulk of the census-sampled material at Falkland compare well in volume with the individual quarries of Laguna del Hunco (ranging from 1.4 to 2.0 m^3 each, Wilf et al., 2005), the Republic sample (1.6 m vertical extent; Passmore et al., 2002), and the Denver Basin sample from locality 2484 (1.0 m^2; Johnson et al., 2003), all of which represent late early to early middle Eocene lacustrine deposits, and therefore form the most secure basis for comparison. The McAbee and Green River samples represent an unknown volume of excavated material, but are lacustrine deposits of an appropriate age.

Non-metric multidimensional scaling (NMDS) was chosen as an ordination technique to explore plant community associations in the three units. NMDS has been found to perform well with ecological data that often is comprised of sparse data sets (with many zeros) with non-normal distribution patterns (McCune and Grace, 2002). NMDS may be used with any distance measure, and will preserve the rank order of among-sample similarities in the distance matrix on which it is based (McCune and Grace, 2002). Fossil data has the added complication of taphonomic bias, in addition to potential sampling error normally associated with ecological community data. Thus, while the absolute numbers of specimens in various taxa cannot be considered an accurate representation of the living plant community, the rank order of the species abundance may be more reliable; i.e. the most common fossil taxa were likely among the most common elements of the local flora, and rare fossil taxa likely comprised minor elements.

NMDS is an iterative technique that searches for the best representation of entities along a number of axes or dimensions. It assesses the stress, or discord, between the representation of the sampling units in reduced dimensions (1–6 axes) compared to the composition of the original matrix, in order to find the best solution with the least amount of stress (McCune and Grace, 2002). The ordination was run on Dataset C (specimens from the two correlative stratigraphic sections). Prior to analysis, some small quarries with very sparse abundance data were amalgamated, but only where the quarries were adjacent and in the same unit. This resulted in a total of 22 quarries in two correlative sections. Unit 1 is represented by nine quarries, Unit 2 by seven quarries, and Unit 3 by six quarries. The Bray-Curtis distance measure (a quantitative form of the Sørenson distance measure) was used to construct the distance matrix.

4.3 RESULTS

4.3.1 Overview of the Falkland Fossil Flora

The Eocene was a time of intense volcanic and tectonic activity in British Columbia, resulting in the development of a topographically diverse landscape that included cool upland niches and the appearance of montane forests (Wolfe, 1987; Wehr, 1998; Greenwood et al., 2005). The extent of microthermal climates in the region was likely restricted during the early

Eocene up to and including the Early Eocene Climatic Optimum; therefore, the establishment of cool upland environments provided an opportunity for expansion of mesothermal lineages into microthermal climates and their subsequent diversification (Wolfe, 1987; DeVore et al., 2005) and the flourishing of microthermal taxa present as minor elements in lowland floras (Wehr and Hopkins, 1994). During the early Eocene, plant families such as Aceraceae (now considered part of Sapindaceae, s.l.), Betulaceae, and Rosaceae underwent rapid diversification, reflected in the fossil record of the Okanagan Highlands (Wolfe, 1987; Wolfe and Wehr, 1987; Wehr, 1995, 1998; DeVore et al., 2005). This pattern of diversification, along with the coexistence of temperate and tropical taxa, is also seen in the insect fossil record of the Okanagan Highlands (Wehr, 1998; Archibald and Mathewes, 2000; Archibald and Farrell, 2003; Greenwood et al., 2005; Archibald et al., 2010).

The Falkland site, although much more limited in both history of collection effort and extent of exposed outcrop compared to other Okanagan Highlands localities such as Republic and McAbee, has produced a diverse assemblage of plant fossils. Gymnosperms are dominated by taxa in Cupressaceae s.l., Pinaceae, and Ginkgoaceae (Fig. 4.2). *Metasequoia occidentalis* (Newberry) Chaney (dawn redwood) foliage is the most commonly encountered fossil at the site, and seed and pollen cones are also present although rare. *Ginkgo adiantoides* (Unger) Heer is also very common, and often features well-preserved cuticle. The fossil cuticle of *Ginkgo adiantoides* has been examined for both taxonomic features and to assess stomatal frequency as a proxy measure of paleoatmospheric CO_2 during the early Eocene (Smith et al., 2010).

Ferns and fern allies are rare features of the Falkland flora, represented by three specimens of fern pinnae (two tentatively assigned to *Adiantum* sp.), the floating fern *Azolla* sp., and *Equisetum* sp. Monocot leaves lacking diagnostic features apart from parallel venation are quite common at the Falkland site, but their taxonomic affiliation remains uncertain. The angiosperm dicot flora at Falkland is diverse, and is particularly rich in taxa from families such as Rosaceae, Betulaceae, and Sapindaceae s.l. (Fig. 4.3). In addition, there are many angiosperm families that are represented by a single taxon or few specimens at Falkland, contributing significantly to the diversity of the flora. Those additional families that include at least one identifiable genus or species are: Lauraceae, Nelumbonaceae, Trochodendraceae, Cercidiphyllaceae, Iteaceae, Grossulariaceae, Ulmaceae, Fagaceae, Myricaceae, Malvaceae s.l., Anacardiaceae, and Theaceae. A preliminary floral list is provided in Table 4.3, and representative specimens are illustrated in Figures 4.2 and 4.3. In addition to formally recognized taxa, there is also a large number of distinct but unidentified morphotypes. Appendix A includes a full overview of the Falkland morphotypes with photographs, descriptions of leaf architecture where applicable, and taxonomic assignment where possible.

4.3.2 Trends in Diversity and Plant Community Composition

4.3.2.1 Species Richness, Diversity and Evenness

To assess species diversity in the Falkland fossil flora, we use Dataset B (ii), limited to angiosperm and gymnosperm foliage morphotypes from census-sampled quarries. Reproductive morphotypes are excluded since the extent of overlap with the foliage morphotypes cannot be fully resolved. This dataset includes 1210 specimens assigned to 78 morphotypes (excluding general morphotypes as discussed above). Figure 4.4 plots three measures of diversity – species richness, the Shannon-Weiner index (H), and evenness (Pielou's J) – for systematically sampled quarries in the three units. Unit 3, the youngest unit, demonstrates highest diversity whether measured by simple species richness or by the Shannon-Weiner index. The evenness of diversity is rather consistent across the three units, ranging from 0.66 in Unit 1 to 0.76 in Unit 3. A t-test for comparing the Shannon-Weiner index from different sampling units (Hutcheson, 1970; Zar, 1999, formulas 8.62–8.65) demonstrates that the difference in diversity in pair-wise comparisons of the three units is significant at α=0.05.

4.3.2.2 Rarefaction Analysis

In comparing the diversities of the three units, it is important to take sample size into consideration. Small sample sizes can create the appearance of low diversity, due to the absence of rare species that only emerge with greater sampling effort, and sample size can influence comparisons of beta diversity across time and/or space (Whitaker, 1972; Raup, 1975; Colwell et al., 2004; Archibald et al., 2010; Vavrek and Larsson, 2010). Unit 1 yielded fewer specimens than either Unit 2 or 3, which could be creating an artificial appearance of lower diversity in that unit. Similarly, Falkland has been much less intensively sampled than some comparative early Eocene sites (e.g. Republic and Laguna del Hunco), and has a smaller volume of exposed outcrop.

In order to analyze changes in diversity over time at the Falkland site, rarefaction analysis was undertaken on abundance data from the three units, using the same dataset as for the determination of species richness and the Shannon-Weiner index, i.e. Dataset B (ii), angiosperm and gymnosperm foliage from census-sampled quarries. If the samples from the three units are rarefied to a standard size of 300 specimens (in order to accommodate the unit with the smallest number of specimens, Unit 1), rarefaction shows that diversity is clearly different between Units 1 and 3, and the rarefaction curves are beginning to diverge at > 300 specimens for Units 2 and 3 (Fig. 4.5). The difference between Units 1 and 2 is not clear at this sample size.

Figure 4.6 presents the rarefaction analysis for Falkland (Dataset D) and other early to middle Eocene sites in North and South America, using dicot leaf morphotypes only. From this analysis, it appears that there are two clusters of diversity, with the Green River curve tracking below both clusters. The highest diversity cluster includes Falkland, Laguna del Hunco Quarry 2 (LH-2), and Río Pichileufú (RP-3). The Río Pichileufú quarry represents a relatively small sample size and the rarefaction curve does not show the marked flattening that would indicate saturation of collection effort; nevertheless, the preliminary RP-3 curve almost exactly tracks that of LH-2. The second cluster of sites includes Republic and the remaining Laguna del Hunco quarries. McAbee and the Denver Basin localities also represent relatively small samples, but appear to fall within the second cluster. The Green River locality has lower diversity than the other sites considered here, with <30 dicot morphotypes at a sample size of 500 from a single quarry at Bonanza River, Utah. The Green River locality appears to have been drier than the other sites considered (Table 4.2), and this may be one explanation for the relatively low diversity observed.

4.3.2.3 Plant Community Dynamics Over Time

In addition to tracking species richness and diversity over time, the changing composition of the plant community at Falkland was investigated. To address this issue, non-metric multidimensional scaling (NMDS) was employed to extract patterns in species abundance and plant community associations across the three units. NMDS has been used in studies of modern vegetation associations and environmental relationships (e.g. Will-Wolf et al., 2006; Royer et al., 2009) as well as in the context of the fossil record (e.g. Vavrek and Larsson, 2010). Individual quarries are coded by unit in the ordination graph (Fig. 4.7), and show a clustering by unit. In particular, Units 1 and 3 are quite distinct from one another, while the quarries from Unit 2 appear to be somewhat transitional, since they span the ordination space between the other two units. As described above, Unit 3 is more diverse than Units 1 or 2, and the NMDS plot suggests that Unit 3 is fairly distinct, at least compared to Unit 1, in terms of plant community composition.

Figure 4.8 presents a spindle diagram of the ten most common taxa in the two correlative sections that were sampled using an unbiased census approach. The dataset used to construct this diagram was Dataset C, the same dataset as for the NMDS ordination (only specimens from the stratigraphic sections), in order to look at comparable volumes of material for the three units. Correlative quarries (i.e. those covering roughly the same stratigraphic interval measured relative to ash layers) in the two sections were amalgamated. The width of the blocks represents the number of specimens of each taxon found in the correlative quarries of the two sections.

With one exception, all ten common taxa were present in all three units, although their relative abundance shifted over time. An exception is the juglandaceous leaf morphotype (FL011) that is only present in Units 2 and 3. The two most abundant taxa at the site, *Ginkgo adiantoides* and *Metasequoia occidentalis*, were present in all three units; however, both reached peak dominance in Unit 2, and were least abundant in Unit 3. *Ginkgo* was notably absent in the quarry immediately above the ash layer marking the transition between Unit 2 and Unit 3. *Ginkgo* made up ~12% of the specimens collected from Units 1 and 2 (based on Dataset B (i), all specimens from all census-sampled quarries) and only ~3% of specimens from Unit 3. Similarly, *Metasequoia* dropped from 20-23% of specimens in Units 1 and 2, to ~13% of specimens in Unit 3. The other taxon that contributes to significant differences between the three units is *Alnus parvifolia* (Berry) Wolfe and Wehr which is present in all three units, but noticeably more abundant in Unit 3.

A contingency table (Table A1, Appendix A) with counts of angiosperm, gymnosperm, and "other" taxa for the three units was used to test for the association between relative abundance of angiosperm and gymnosperm specimens in the three units, utilizing Dataset B (i). The chi-square test for independence shows a highly significant association ($p<0.001$) between position in section and relative abundance of major taxonomic groups. In Units 1 and 2, angiosperm and gymnosperm specimens were found in roughly equal numbers, while Unit 3 shows a marked increase in the relative abundance of angiosperms (Fig. A1, Appendix A). In all cases, dicots comprise the vast majority of the angiosperm specimens.

4.4 DISCUSSION

Several patterns emerge from the preceding analyses of plant diversity within the Falkland site, and among early Eocene sites in North and South America. Rarefaction analysis (Fig. 4.6) confirms the high diversity status of early Eocene mid-latitude sites in general, and Falkland in particular, and demonstrates that diversity does not necessarily correlate with latitude or mean annual temperature in the Eocene world, as neither the warmest site (Denver Basin locality 2484) nor the lowest latitude sites (Denver Basin and Green River) show the highest diversity. This agrees with recent findings on latitudinal gradients and insect diversity in the early Eocene, indicating that equability of climate allowed the development of high-diversity biotic communities even in areas with relatively low thermal insolation (Archibald et al., 2010). In their study of insect diversity, Archibald et al. (2010) also compared the diversity of the McAbee flora to modern day leaf litter samples from both tropical rainforest (Ella Bay, Queensland, Australia) and temperate broadleaf-deciduous forest (Harvard Forest, Massachusetts), and found the McAbee site to be more similar to the tropical rainforest samples in diversity. The Eocene sites considered here meet or exceed the levels of diversity at McAbee (with the exception of the Green River quarry and possibly LH-4; Fig. 4.6) and therefore compare favourably with modern tropical levels of plant diversity at rarefied sample sizes. Data on modern tropical rainforest diversity from Panama and Brazil (Wing et al., 2009) confirm this, as Falkland dicot diversity is similar to that reported for a sample taken from a wet lakeshore on Barro Colorado Island, Panama (sample BCI-D, Wing et al., 2009; Fig. 4.9). In contrast, diversity of a modern temperate deciduous forest at mid-latitude (Harvard Forest) is much lower than either the early Eocene sites, or the modern tropical sites (Archibald et al., 2010; Fig. 4.9).

This result appears to contradict the suggestion of a steeper-than-modern latitudinal gradient of floral diversity in the Northern Hemisphere, based on pollen (Harrington, 2004). Following that pattern, we would expect rather low levels of diversity at this mid-latitude site, which is demonstrably not the case. Archibald et al. (2010) suggested that the key factor in supporting high diversity is equability in climate, rather than simply high MAT. Falkland, like other fossil localities in the early Eocene (Wing and Greenwood, 1993), had an equable climate (i.e. low thermal seasonality), with the cold month mean temperature >0˚C (Smith et al., 2009) indicating a lack of prolonged freezing temperatures. Therefore, even with a relatively cool MAT, Falkland was able to support a highly diverse biotic community.

Results presented here also suggest that not only was diversity high at the Falkland site, consistent with data for other Okanagan Highland early Eocene sites, but that the plant community was becoming more diverse over time. In particular, we see increasing diversity of minor angiosperm taxa at the site, although the dominant taxa remain present over the span of time represented by the exposed outcrop. These results suggest that a common suite of foundational taxa were present in all three units, although varying in relative abundance over time, while the introduction of minor dicot elements contributed to higher diversity in Unit 3. The results of the NMDS ordination (Fig. 4.7) show a clustering of quarries in the three units, primarily in terms of the two end units of Unit 1 and Unit 3. If there were only a single plant community represented at the site, we would expect to see the quarries spread randomly across the ordination space, irrespective of their assignment to unit. While not perfect in terms of clustering into units, there is a distinct grouping (Fig. 4.7), especially vis-à-vis quarries from Units 1 and 3. The quarries from Unit 2 appear to be transitional, and it is not possible to resolve whether the change from Unit 1 to 3 is continuous or abruptly defined by the unit boundaries, given the overlap in clusters.

In looking at change within the plant community at the Falkland site, there are various factors that might influence the composition, stability, and diversity of the community. The Falkland site likely represents a relatively short time interval, perhaps in the range of 10^3–10^4 years based on sediment accumulation rates (0.36 to 0.47 m/1,000 yrs) from the coeval Okanagan Highlands Horsefly locality which features varved sediments (Barton, 1998). Evolutionary processes can likely be disregarded on this timescale. Other possible factors that warrant consideration include: changes in climate, leading to shifts in the ranges of plant communities and in-migration from adjacent areas of lower or higher altitude and/or latitude; changes in the depositional environment, leading to different taphonomic factors influencing the composition of the fossil assemblage; and patchiness in the local landscape due to microhabitat variation and response to repeated disturbance events (Greenwood and Basinger, 1993; Moss et al., 2005).

Leaf margin analysis of dicots from the three units of the Falkland site indicates that MAT was decreasing over the time (Table 4.4). It is unclear whether this climatic change represents a short-term fluctuation, or is part of a longer-term trend in the waning phase of the Early Eocene Climatic Optimum. The precipitation at the site was consistently high for the three units (>100 cm/yr), using leaf area analysis (Wilf et al., 1998), with the values for the three units not statistically distinguishable given the large error ranges (Table 4.4). Analysis of the stomatal frequency of *Ginkgo* leaves in the three units of the Falkland site (Smith et al., 2010) further suggests that declining temperatures were accompanied by decreasing levels of pCO_2. This change in climate may have resulted in shifts in plant ranges from adjacent areas, with taxa suited to cooler climates migrating from higher elevations or latitudes. However, intuitively we might expect a cooling climate to mark a shift towards greater abundance of conifers, rather than dicot taxa, which is not the pattern observed in Unit 3. Lower pCO_2 may result in physiological drought, as plants increase stomatal frequency to facilitate gas exchange for photosynthesis, thereby increasing rates of stomatal conductance and water loss (McElwain et al., 2005). Dicots have more efficient water conductance relative to conifers through the evolution of vessel elements, and dicots may therefore be better adapted to lower pCO_2 regimes (McElwain et al., 2005). However, the magnitude of change in pCO_2 between the three units is not known in absolute terms, due to limitations in the stomatal frequency methodology (Smith et al., 2010), and the timescale represented by the three units may not be sufficient for this explanation to be convincing.

In examining fossil assemblages from 25 localities in the Okanagan Highlands (but not including Falkland), Wilson (1980) inferred correlations between the composition of the fossil assemblages and estimated lake water-depth and distance from shore. His model proposed a correlation between deep water/off-shore depositional environments and fossil assemblages dominated by *Amyzon* fish fossils with little evidence of decay, a greater proportion of complete insects dominated by strong fliers, and relatively more dicot leaves compared to conifer needles and taxodiaceous leaves. In comparison, he proposed that near-shore assemblages tended to be more diverse in plant fossils, but with more conifer needles and taxodiaceous foliage relative to dicots, and more incomplete insect fossils with a bias towards weaker fliers.

Wilson's model does not entirely explain the differences in the fossil assemblages observed in the three units of the Falkland site. Based on trends in diversity, the model would suggest that Units 1 to 3 reflect a gradually diminishing lake-depth, with Unit 3 representing a shallow-water/near-shore environment with the most diverse assemblage. However, based on the relative abundance of dicots compared to gymnosperms, this model would suggest that Unit 3 represents a deeper-water environment relative to Units 1 and 2, with its high abundance of dicot leaf specimens. In terms of the insect fauna, all three units are dominated by march flies (Diptera: Bibionidae; S.B. Archibald, pers. comm. 2009), which Wilson (1980) associates with near-shore environments. Units 1 and 3 are similar in lithology, being dominated by shales suggesting low-energy deposition (Smith et al., 2009). Unit 2 appears to be a higher energy environment, with lithology including siltstones and sandstones and the wave-ripple mark horizon, and shows the most evidence of disturbance (Smith et al., 2009). Taken together, these lines of evidence do not show a clear demarcation between near-shore and off-shore depositional environments in the three units, although there is evidence of lake levels becoming shallower for at least a brief period in Unit 2. Archibald and Makarkin (2006) suggested that the formation of diatom mats in some Okanagan Highlands localities were an important taphonomic factor, providing a medium for preservation and passive transport of insect and plant remains from near-shore to off-shore locations, thus obscuring some patterns of aerial transport and sorting suggested in Wilson's (1980) model.

Moss et al. (2005) examined pollen samples from Falkland as part of a regional study of Okanagan Highlands sites. Their samples are not placed in a stratigraphic context, but are noted to have been in close lateral and vertical proximity. Despite this, however, the three Falkland samples analyzed showed a great deal of variation in relative abundance of three main vegetation associations identified by Moss et al. (2005). Their three associations included: 1) fir-spruce, modeled as dominant in higher ridge and north-slope aspect environments; 2) birch-golden larch, modeled as dominant in local lakeshores and streamsides; and 3) palm-cypress, modeled as mesothermal-megathermal taxa restricted to specialized habitats lower in elevation or on warm, south facing slopes. Two of the samples showed similar proportions of the fir-spruce and birch-golden larch associations (35–55% and 45–65% respectively in the two samples), although with variation in abundance of individual taxa within these associations. Their third sample, however, showed a marked shift towards dominance of the birch-golden larch association (92%) and the introduction of a minor palm-cypress element (~3%). Moss et al. (2005) suggested that the differences in the Falkland pollen samples reflect local patchiness in microhabitat due to variation in water-table depth or edaphic factors, and/or different seral stages in response to disturbance in the landscape in the form of volcanism and fires (see also Greenwood and Basinger, 1993).

At the Falkland site, Unit 2 encompasses the portion of the outcrop that shows the most environmental disturbance, as it contains not only multiple volcanic ash layers (which are also found in the other two units) but also a horizon showing wave ripple marks, indicating a possible climate fluctuation affecting lake levels, followed by a distinctive “fish kill” layer which includes numerous articulated and disarticulated fish remains (Smith et al., 2009). Volcanic activity has significant implications for the development of plant communities, depending on distance from the eruptive centre, the degree and frequency of the eruptions, and the presence and location of biotic refugia (del Moral and Wood, 1993; Harris and Van Couvering, 1995; Jolley et al., 2008). Jolley et al. (2008) have examined the influence of volcanic activity on the nutrient availability for plant communities in the fossil record, using material from the Miocene Columbia River flood basalts in northwestern United States. The plant communities documented in the interbed layers of those formations often show diverse and highly productive plant assemblages that would have received large inputs of macronutrients from weathering of volcanic material in the surrounding landscape, transported through the hydrological system during quiescent periods. Nutrient input is affected by distance from eruptive centre, precipitation levels, and degree of weathering of volcanic materials (Jolley et al., 2008). The Falkland site is clearly embedded in a volcanically active landscape, and may have received nutrient inputs through the weathering of volcanic materials (or airborne deposition) in the high precipitation regime suggested by the fossil flora. Over time, volcanic soils may become depleted in nutrients such as P and N (Jolley et al., 2008). The presence of nitrogen-fixing taxa such as *Alnus* sp., abundant at Falkland and in particular in the youngest unit (Unit 3), would have enhanced the bioavailability of limiting nutrients, contributing to the recovery and succession of the plant communities following disturbance.

It is difficult to separate the potential impacts of changing climate, depositional environment, and disturbance regime, as these may be linked to a certain extent; it does not seem that any one of these factors in isolation can account for the patterns observed in plant diversity and dynamics at the Falkland site. Given the evidence for changing climate, declining pCO_2, an active disturbance regime, and a high degree of heterogeneity in the local landscape, it seems likely that the patterns observed in the Falkland flora reflect a combination of these factors. The change in climate over time, and the intensifying disturbance regime seen in Unit 2, may have marked a “threshold zone” (Muradian, 2001; Huggett, 2005) in environmental conditions, precipitating the shift towards the plant community observed in Unit 3.

4.5 CONCLUSION

The fossil flora at the Falkland site is diverse, despite having a relatively cool upland climate, and is comparable in diversity to the hyper-diverse Eocene Laguna del Hunco site in Argentina. Similar to other fossil localities in the Okanagan Highlands, the Falkland flora includes many taxa in plant families such as the Pinaceae, Rosaceae, Betulaceae, Ulmaceae and Sapindaceae. There is growing evidence that the early Eocene Okanagan Highlands were hotspots for the diversification of many temperate plant families, as the upland environments provided new niches for the flourishing of microthermal elements in the warm Eocene world (DeVore et al., 2005).

By examining trends in plant community diversity, structure, and composition, it is possible to track changes over time at the Falkland site. The three units at the Falkland site share a foundational assemblage of dominant plant taxa, including *Metasequoia*, *Ginkgo*, and *Alnus* that shift in relative abundance over time. Minor dicot elements increase through the section, leading to highest diversity in the upper (youngest) unit at the site. This unit also shows a marked increase in the relative abundance of angiosperm specimens. Unit 3 follows a time of environmental disturbance, as reflected in the stratigraphy of Unit 2, and also gives the coolest MAT and lowest pCO_2 signal of the three units. This cooling may represent a short-term fluctuation, or be part of a longer-term trend as the site age falls within the waning phase of the Early Eocene Climatic Optimum. It is proposed here that environmental disturbance and climate change factors interacted to create a threshold zone, precipitating the shift to a plant community more dominated by angiosperm taxa, including a diverse dicot element, as observed in the upper (youngest) unit of the site. The increasing abundance and diversity of dicots, and the dominance of *Alnus* in particular in Unit 3 as discussed above, may reflect an intensifying disturbance regime, with dicots more likely to form early seral stages of plant communities, and better able to recover from repeated disturbance events.

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TABLE 4.1. DETAILS OF DATASETS USED IN ANALYSES

Dataset identifier	Shorthand reference	Description	# of specimens/ # of morphotypes
A	Full dataset	All specimens, including census and biased collections, all morphotypes.	2052/143* 1561/138†
B(i)	Census all	All specimens collected from census-sampled quarries, including general morphotypes.	1843/120
B(ii)	Census foliage	All angiosperm and gymnosperm foliage specimens assigned to specific morphotypes collected from census-sampled quarries; excluding reproductive morphotypes.	1210/78§
C	Stratigraphic sections	All specimens assigned to specific morphotypes collected from the two correlative sections of ~2.5 m.	965/98§
D	Census dicots	Including only dicot foliage morphotypes collected from census-sampled quarries; excluding general morphotypes FL99 and FL990.	486/62§

*Including general morphotype categories.
†Excluding general morphotype categories.
§Morphotypes FL21 and FL81 treated as a single morphotype.

TABLE 4.2. DETAILS OF EARLY EOCENE MID-LATITUDE FOSSIL LOCALITIES USED FOR RAREFACTION ANALYSIS

Locality	Age (Ma)	Paleolatitude*	No. dicot morphotypes	No. specimens	MAT (°C)	MAP (cm/yr)	Depositional setting	References
Falkland	50.61 ± 0.16	~54°N	62	486	9.5 ±2.2[†]	118 +51/-36	Lacustrine (upland)	This paper
McAbee	52.90 ± 0.83	~54°N	23	125	10 to 13.5[§]	108 ±35[#]	Lacustrine (upland)	Greenwood et al. (2005), Archibald et al. (2010)
Republic	49.42 ± 0.54	~52°N	58	1019	9.1 to 13.5[§]	115 ±39[#]	Lacustrine (upland)	Passmore et al. (2002), Wilf et al. (2003), Greenwood et al. (2005)
Green River (Bonanza, Utah)	~43 to 48	~43°N	N.A.	N.A.	15	84	Intermontane lake	Wilf et al. (2001), Wilf et al. (2003)
Denver Basin (DMNH 2484)	~54	~42°N	33	248	25.2 ±2.1	131 +56/-40	Lacustrine (lowland)	Johnson et al. (2003)
Río Pichileufú (RP-3)	47.46 ± 0.05	~46°S	39	213	19.2 ±2.4	N.A.	Lacustrine	Wilf et al. (2005)
Laguna del Hunco (LH) LH – All quarries	51.91 ± 0.22	~47°S	132	3193	16.6 ±1.3	114 +49/-34	Lacustrine	Wilf et al. (2003, 2005)
LH-2	51.91 ± 0.22	~47°S	61	609	18.2 ±1.9	105 +45/-32	Lacustrine	Wilf et al. (2003, 2005)
LH-4	51.91 ± 0.22	~47°S	53	1248	16.7 ±2.1	123 +53/-37	Lacustrine	Wilf et al. (2003, 2005)
LH-6	51.91 ± 0.22	~47°S	45	530	17.8 ±2.3	114 +49/-34	Lacustrine	Wilf et al. (2003, 2005)
LH-13	51.91 ± 0.22	~47°S	55	806	14.5 ±2.0	110 +47/-33	Lacustrine	Wilf et al. (2003, 2005)

Notes: MAT – mean annual temperature; MAP – mean annual precipitation; N.A. – data not available.

* Paleolatitude of the Falkland site calculated using the resources provided on the Ocean Drilling Stratigraphic Network GEOMAR website http://www.odsn.de/odsn/index.html (note: website now offline). Other paleolatitudes are estimated according to modern position relative to Falkland, assuming roughly the same positioning in the early Eocene. Paleolatitudes for Río Pichileufú and Laguna del Hunco are given in Wilf et al. (2003, 2005), and were also estimated using the ODSN service.

[†] We use the LMA formula provided in Kowalski and Dilcher (2003) for calculating MAT. If same formula is used as for the South American sites and Denver Basin, MAT is estimated at 7.3±2.0. CLAMP analysis gives an estimate of 12.5˚C for Falkland.

[§] Range of estimates from LMA, CLAMP and bioclimatic (nearest living relative) analysis, provided in Greenwood et al. (2005), encompassing the range of estimates in the literature.

[#] Estimated from bioclimatic analysis in Greenwood et al. (2005).

TABLE 4.3. PRELIMINARY FLORAL LIST FOR THE FALKLAND SITE, WITH OCCURRENCE IN UNITS

Taxon or morphotaxon (organ; morphotype no.; reference specimen no.)	Unit 1	Unit 2	Unit 3	Scree
EQUISETALES				
Equisetaceae				
Equisetum sp. (A/F; FL098; 07-0229)	-	+	+	+
POLYPODIALES				
Pteridaceae				
?Adiantum sp. 1 (F; FL131; 07-0852)	-	-	-	+
?Adiantum sp. 2 (F; FL167; 08-0064)	+	-	-	-
Azollaceae				
Azolla sp. (F; FL164; 07-0963)	-	-	-	+
Incertae sedis				
Fern sp. 1 (F; FL146; 07-0816)	+	-	-	-
GINKGOALES				
Ginkgoaceae				
Ginkgo adiantoides (Unger) Heer (F; FL004; 07-0067)	+	+	+	+
Ginkgo dissecta Mustoe (F; FL096; 08-0009)	-	+	-	-
CONIFERALES				
Pinaceae				
Abies milleri Schorn and Wehr (F, CS, S; FL074, FL062, FL0136; 07-0665, 06-0967, 07-0875)	+	+	+	+
Picea sp. (F, S; FL089, FL091; 08-0028, 08-0030)	+	+	+	+
Pinus sp. (F, SC, S; FL033, FL101, FL019; 07-0913, 06-1028; 06-0940)	+	+	+	+
Pseudolarix sp. (F, S; FL052, FL138; 07-0802, 07-0957)	+	+	+	+
Pinaceae sp. (PC; FL142; 06-0116)	-	-	+	-
Cupressaceae s.l.				
Chamaecyparis sp. (SC; FL113; 06-1034)	-	-	+	+
Cunninghamia sp. (F; FL090; 06-0047)	-	-	+	-
Cupressinocladus interruptus (Newberry) Schweitzer (F; FL149; 07-834)	+	-	-	+
?*Glyptostrobus* sp. (F; FL150; 07-500)	+	+	+	-
Metasequoia occidentalis (Newberry) Chaney (F, SC, PC; FL012, FL059, FL139; 07-0197, 06-0404, 06-0374)	+	+	+	+
Sequoia affinis Lesquereux (F, PC; FL037, FL061; 06-0123, 06-0042)	+	+	+	+
Taxodium dubium (Sternberg) Heer (F; FL055; 06-0425)	+	+	-	-
Cupressaceae sp. (F; FL031; 08-0059)	+	+	+	+
Incertae sedis				
Conifer foliage sp. 1 (F; FL064; 06-0811)	-	-	+	-
Conifer foliage sp. 2 (F; FL156; 06-0959)	-	+	-	-
Conifer pollen cone (PC; FL036; 06-0849)	-	-	+	-
MONOCOTS				
Monocot sp. 1 (F; FL005; 06-0268)	+	+	+	-
Monocot sp. 2 (F; FL130; 07-0851)	-	-	-	+
cf. *Musophyllum complicatum* Lesquereux (F; FL123; 06-0113)	+	-	+	-
DICOTS				
LAURALES				
Lauraceae				
Sassafras hesperia Berry (F; FL003; 07-0842)	+	+	+	+
?Lauraceae sp. (F; FL015; 06-0293)	-	+	-	+
PROTEALES				
Platanaceae				
Macginitea sp.*	-	-	-	-
Nelumbonaceae				
Nelumbo sp. (F; FL165; 07-0965)	-	-	-	+
TROCHODENRALES				
Trochodendraceae				
Tetracentron sp. (F; FL161; 07-0962)	-	-	-	+
Trochodendron sp. (Fr; FL051; 06-0114)	-	-	+	-
Zizyphoides sp. (F; FL122; 06-0697)	-	+	-	-
SAXIFRAGALES				
Cercidiphyllaceae				
Cercidiphyllum/*Joffrea* sp. (F, Fr; FL007, FL053; 06-0977, 06-0337)	-	+	-	+
Grossulariaceae				
Ribes sp. (F; FL088; 08-0001)	+	+	+	+
Hamamelidaceae				
Hamamelidaceae sp. (F; FL141; 07-0893)	-	+	-	-
Iteaceae				
cf.*Itea* sp. of Wolfe and Wehr ,1987 (F; FL115; 07-0199)	+	+	+	-
MALPIGHIALES				
Salicaceae				
?Salicaceae sp. 1 (F; FL028; 06-0152)	-	-	+	-
?Salicaceae sp. 2 (F; FL080; 07-0455)	+	-	-	-
ROSALES				
Rosaceae				
Photinia pagae Wolfe and Wehr (F; FL114; 07-0251)	+	+	+	+
?*Prunus* sp. (F; FL163; 07-0932)	-	-	+	+
cf.*Prunus* sp. (Fl; FL166; 08-0048)	-	-	-	+
cf. *Malus idahoensis* Brown (F; FL013; 08-0016)	-	+	+	+
cf. *Crataegus* sp. (F; FL145; 08-0023)	-	-	+	+
?*Holodiscus* sp. (F; FL002; 06-0341)	-	-	+	-

cf. *Spiraea* sp. (F; FL040; 06-0733)	-	+	+	-
Rosaceae sp. 1 (F; FL093; 08-0019)	+	-	-	+
Rosaceae sp. 2 (F; FL132; 07-0854)	-	-	-	+
Ulmaceae				
Ulmus okanaganensis Denk and Dillhoff (F; FL021, FL081; 06-0970, 07-0736)†	+	+	+	+
Ulmus sp. (Fr; FL032; 06-0054)	+	+	+	+
FAGALES				
Fagaceae				
Fagus langevinii Manchester and Dillhoff (F; FL044; 07-0877)	-	+	+	+
?*Quercus* sp. (F; FL079; 07-0191)	-	-	+	-
Betulaceae				
Alnus parvifolia (Berry) Wolfe and Wehr (F, I; FL023, FL065; 07-0791, 08-0029)	+	+	+	+
Alnus sp. 1 (F; FL020; 06-0375)	+	+	+	+
Alnus sp. 2 (F; FL117; 07-0244)	-	+	-	+
Alnus sp. 3 (F; FL159; 07-0814)	+	+	+	-
Betula leopoldae Wolfe and Wehr (F; FL034; 07-0195)	+	+	+	-
?*Corylus* sp. (F; FL026; 06-0168)	+	-	+	-
Betulaceae sp. 1 (I; FL006; 07-0915)	-	+	+	+
Betulaceae sp. 2 (I; FL124; 07-0346)	+	+	+	+
Myricaceae				
Comptonia columbiana Dawson (F; FL001; 06-0001)	-	-	+	+
Juglandaceae				
Juglandaceae sp. (F; FL011; 06-0893)	-	+	+	+
MALVALES				
Malvaceae s.l.				
Florissantia quilchenensis (Mathewes and Brooke) Manchester (Fl; FL042; 07-0084)	+	+	+	+
SAPINDALES				
Anacardiaceae				
Rhus malloryi Wolfe and Wehr (F; FL127; 07-0158)	-	-	+	-
Sapindaceae s.l.				
Acer sp. 1 (F; FL050; 07-0785)	-	-	+	-
Acer sp. 2 (Fr; FL066; 07-0559)	-	+	-	+
Acer sp. 3 (Fr; FL095; 08-0031)	-	+	+	+
Aesculus sp. (F; FL069; 06-0262)	+	-	+	-
Bohlenia americana (Brown) Wolfe and Wehr (F; FL097; 07-0576)	-	+	-	-
Deviacer sp. (Fr; FL147; 07-0770)	+	-	-	-
Dipteronia brownii McClain and Manchester (Fr; FL108; 07-0807)	+	-	-	+
Koelreuteria arnoldi Becker (Fr; FL104; 08-0035)	-	-	-	+
ERICALES				
Theaceae				
Ternstroemites sp. B of Wolfe and Wehr, 1987 (F; FL022; 06-0036)	-	+	+	-
Incertae sedis				
24 Indet. dicot toothed leaf types (FL009, 06-0118; FL010, 06-0183; FL014, 06-0786; FL016, 06-0859; FL018, 08-0013; FL029, 06-0091; FL030, 06-0746; FL039, 06-0935; FL049, 06-0156; FL054, 07-0610; FL056, 06-0195; FL057, 07-0284; FL067, 06-0826; FL082, 06-0724; FL084, 06-0918; FL086, 06-0408; FL100, 06-1040; FL110, 08-0053; FL111, 08-0055; FL116, 07-0140; FL140, 07-0887; FL143, 06-0723; FL153, 08-0051; FL160, 07-0871)	+	+	+	+
12 Indet. dicot entire leaf types (FL008, 06-0587; FL024, 06-0650; FL025, 06-0649; FL035, 06-0302; FL047, 06-0545; FL077, 06-0929; FL102, 06-1029; FL118, 07-0062; FL126, 07-0279; FL128, 07-0841; FL144, 07-0137; FL152, 07-0783)	+	+	+	+
Indet. dicot leaf type margin indistinct (FL134, 07-0305)		+		
16 Indet. reproductive structures (Fl, FL041, 06-0214; Fl, FL068, 06-0604; Fl, FL075, 06-0024; Fl, FL121, 07-0828; Fl, FL129, 06-1036; Fr?, FL060, 06-0090; Fr, FL063, 06-0856; Fr, FL105, 08-0037; Fr, FL109, 06-1031; Fr, FL137, 06-0605; Fr, FL162, 06-1044; Fr, FL148, 07-0203; I, FL120, 07-0818; I, FL155, 06-1037; I, FL158, 06-1042; S, FL045, 07-0850)	+	+	+	+
Indet. ?moss sp. (F; FL103; 07-0793)		+		

Notes: Representative specimens are illustrated in Figs. 4.2 and 4.3. Full descriptions of all morphotypes are provided in Appendix A. Organs: A – axis; F – foliage; SC – seed cone; PC – pollen cone; CS – cone scale; S – seed; Fl – flower; Fr – fruit; I – inflorescence/infructescence. All morphotype numbers are preceded by FL for Falkland. All specimen numbers are field-assigned numbers preceded by RYS in database (prefix omitted in table for brevity). ? – tentative assignment to taxon; aff. – morphological affinities to taxon; cf. – no characters contradict assignment, but assignment uncertain.

* Reported by Greenwood et al. (2005) but not encountered during fieldwork for this study.

† Two foliage morphotypes for this taxon (FL021 and FL081, representing elongation and young shoot leaves) are maintained in the morphotype database, but are treated as a single species in all analyses.

TABLE 4.4. DETAILS OF FOSSIL SPECIMENS COLLECTED AT THE FALKLAND SITE (DATASET A) AND PALEOCLIMATE ESTIMATES

Sample	Unit 1	Unit 2	Unit 3	Scree*	Whole site
Plant specimens:					
Total	508	662	738	144	2052
Identifiable to morphotype	342 (67%)	528 (80%)	549 (74%)	142 (99%)[†]	1561 (76%)
Dicot leaves	81	180	247	58	566
Dicot reproductive	12	34	53	37	136
Monocots	7	8	19	1	35
Gymnosperm leaves	228	285	201	30	744
Gymnosperm reproductive	7	16	15	11	49
Ferns and horsetails	2	1	1	3	7
Other	5	4	13	2	24
Paleoclimate:					
Dicot leaf specimens entire (%)	25.0%	16.2%	10.2%	N.A.	20.0%
Estimate of MAT (°C)[§]	11.3 ±3.6	8.1 ±2.5	5.9 ±2.0	N.A.	9.5 ±2.2
Mean area of dicot leaves, ln (mm^2)	7.37	7.38	7.24	N.A.	7.31
Estimate of precipitation (cm/yr)[#]	122 +53/-37	123 +53/-37	114 +49/-34	N.A.	118 +51/-36

Note: N.A. – not applicable.

* Stratigraphic context unknown.

[†] Scree specimens were collected specifically to improve the reference collection of morphotypes, and therefore have a high percentage of specimens assignable to morphotype.

[§] Calculated using formula from Kowalski and Dilcher (2003); error is the larger of the sampling error as calculated using the formula in Miller et al. (2006) or 2°C minimum (Wilf,1997).

[#] Calculated using formula from Wilf et al. (1998); error is asymmetrical as converted from log values.

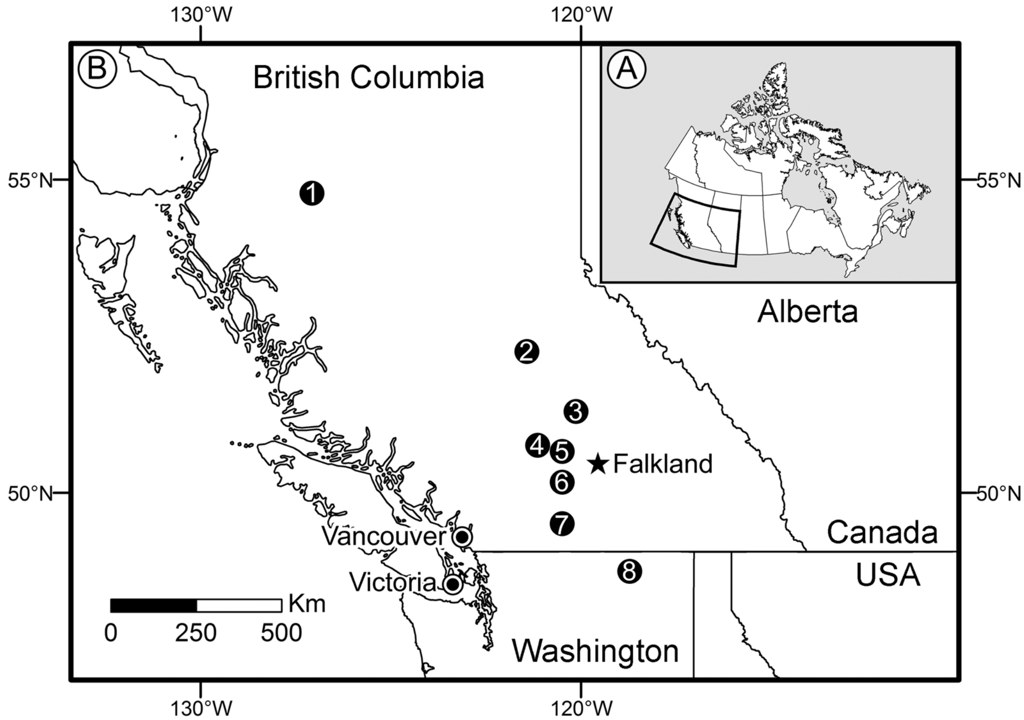

Fig. 4.1. Map showing study site location (Falkland) in British Columbia, Canada, along with other Okanagan Highlands fossil localities. A) Outline map of Canada, with GIS data provided by The Atlas of Canada (Department of Natural Resources Canada). B) Detail of portion of British Columbia, Canada and Washington, USA with Okanagan Highlands fossil localities: 1) Driftwood Canyon; 2) Horsefly; 3) Chu Chua; 4) McAbee; 5) Tranquille; 6) Quilchena; 7) Princeton (including One Mile Creek); 8) Republic, WA.

Fig. 4.2. Representative specimens of the Falkland flora (gymnosperms, ferns and fern allies, monocots). All scale bars = 1 cm. A) *Picea* sp. defoliated axis, RYS08-0028; B) *Picea* sp. seed, RYS08-0030; C) *Abies milleri* seed, RYS07-0875; D) *Abies milleri* foliage, RYS07-0665; E) *Pinus* sp. seed, RYS06-0940; F) *Pseudolarix* sp. seed, RYS07-0957; G) *Abies milleri* cone scale, RYS06-0967; H) *Pseudolarix* sp. needle, RYS07-0802; I) *Pinus* sp. foliage (5-needled), RYS06-1035; J) *Metasequoia occidentalis* pollen cones, RYS06-0374; K) *Metasequoia occidentalis* seed cone, RYS06-0404; L) *Metasequoia occidentalis* foliage, RYS07-0197; M) Cupressaceae sp. foliage, RYS07-0181; N) *Chamaecyparis* sp. seed cone, RYS06-1034; O) *Sequoia affinis* foliage, RYS06-0123; P) *Sequoia affinis* pollen cones, RYS06-0042; Q) *Cunninghamia* sp. foliage, RYS06-0047; R) *Taxodium dubium* foliage, RYS06-0425; S-V) *Ginkgo adiantoides* foliage, RYS08-0022, RYS07-0067, RYS07-0941, RYS08-0002; W) *Ginkgo dissecta* foliage, RYS08-0009; X) ?*Adiantum* sp., RYS07-0852; Y) *Equisetum* sp., RYS07-0933; Z) monocot, RYS06-0268.

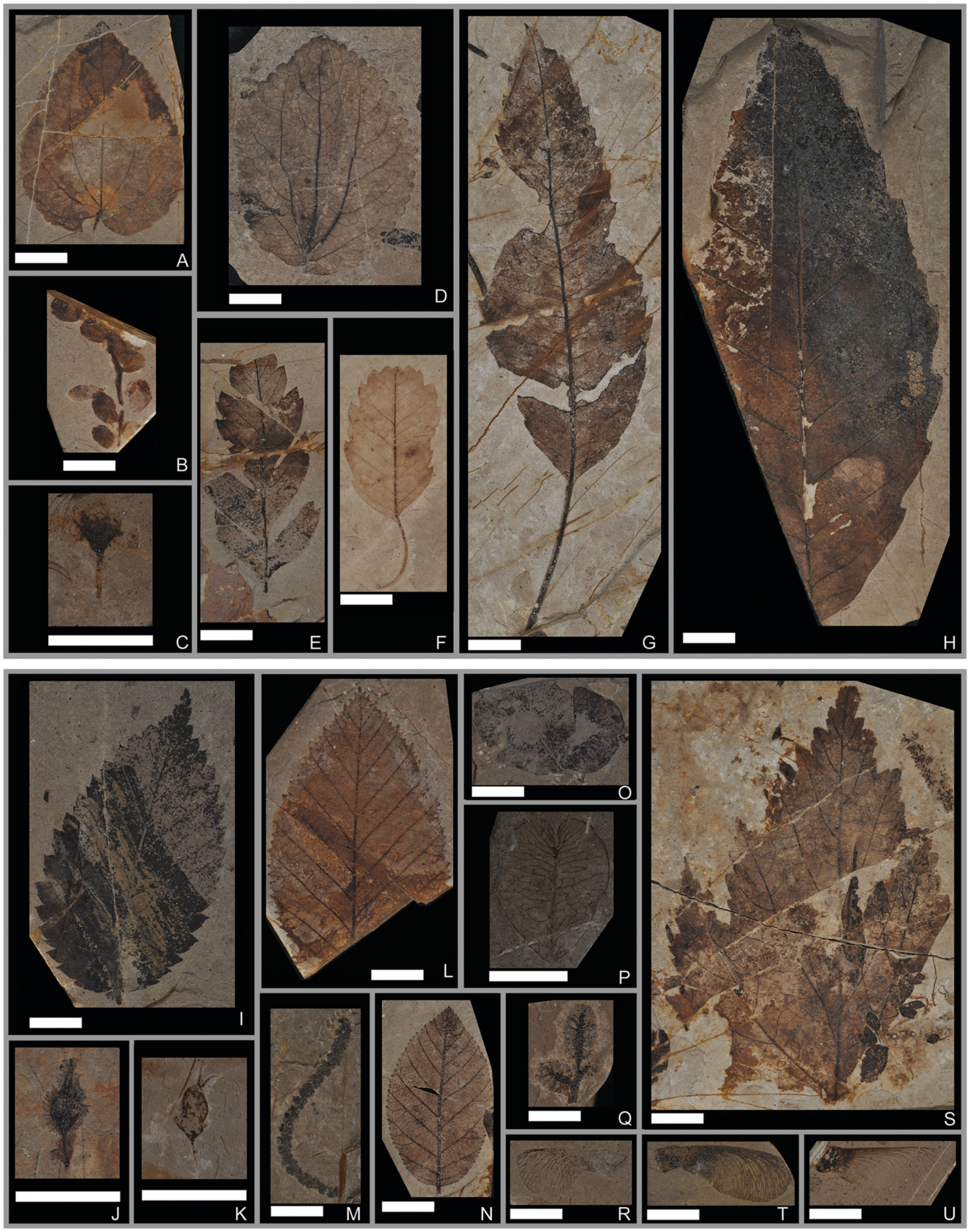

Fig. 4.3. Representative specimens of the Falkland flora (dicots). All scale bars = 1 cm. A) *Tetracentron* sp., RYS07-0962; B) *Joffrea* sp. fruit, RYS06-0337; C) *Trochodendron* sp. fruit, RYS06-0114; D) Cercidiphyllaceae sp., RYS06-0977; E) c.f. *Crataegus* sp., RYS08-0023; F) Rosaceae sp., RYS08-0019; G) *Photinia pagae*, RYS07-0251; H) *Fagus langevinii*, RYS07-0877; I) *Ulmus okanaganensis*, RYS06-0970; J) *Ulmus* sp. samara (note preservation of peripheral hairs), RYS08-0062; K) *Ulmus* sp. samara, RYS06-0054; L) *Betula leopoldae*, RYS07-0195; M) betulaceous staminate catkin, RYS07-0915; N) *Alnus parvifolia*, RYS07-0791; O) *Dipteronia brownii*, RYS07-0807; P) *Koelreuteria arnoldi*, RYS08-0035; Q) *Alnus parvifolia* pistillate catkin, RYS06-1032; R) *Acer* sp. samara, RYS08-0036; S) *Acer* sp., RYS07-0785; T) *Acer* sp. samara, RYS08-0031; U) *Acer* sp. samara, RYS07-0562.

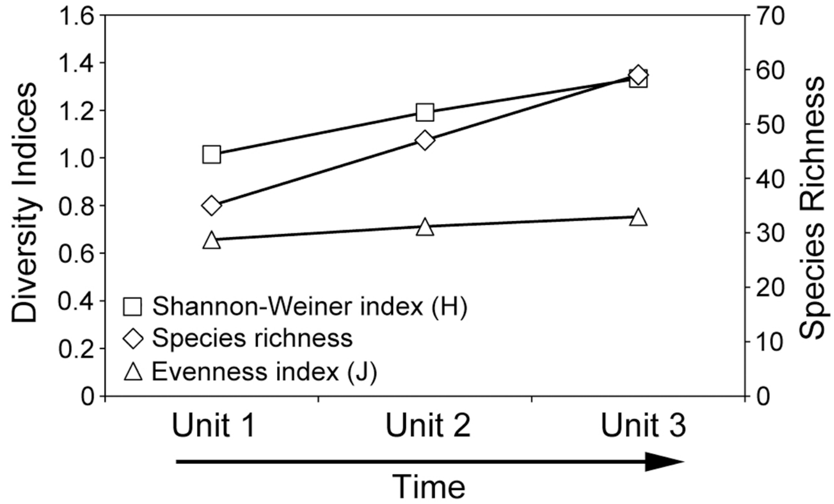

Fig. 4.4. Comparison of species richness and diversity for the three units at the Falkland site using Dataset B (ii), angiosperm and gymnosperm foliage from census quarries.

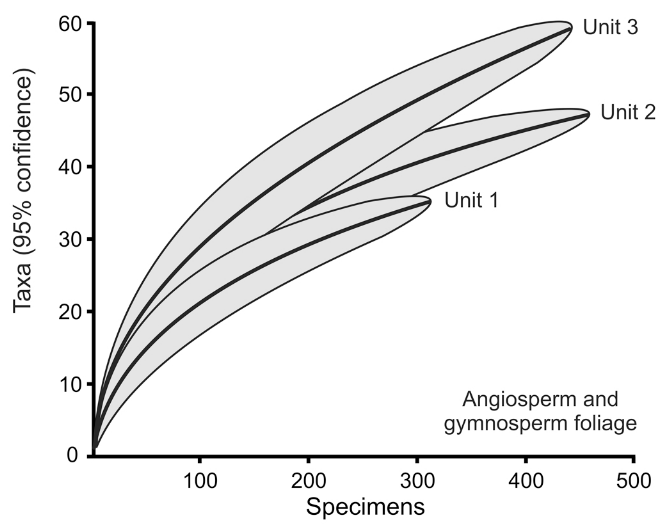

Fig. 4.5. Rarefaction analysis of three units at the Falkland site using Dataset B (ii), angiosperm and gymnosperm foliage from census quarries. See Table A2 (Appendix A) for raw abundance data.

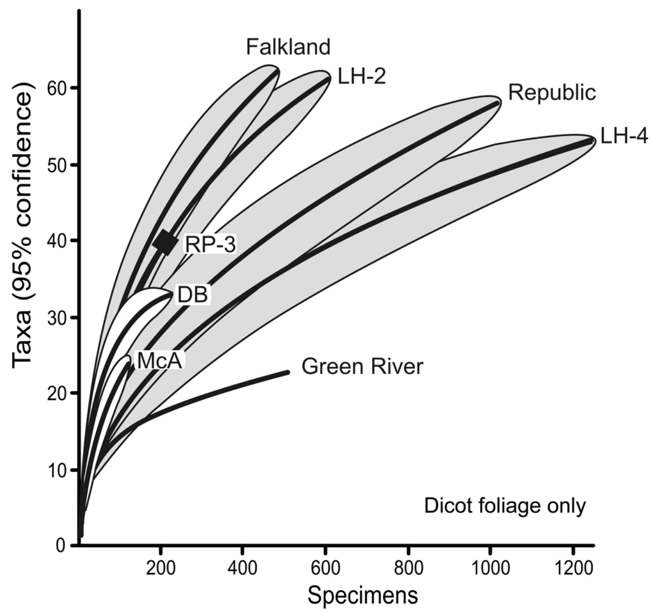

Fig. 4.6. Rarefaction analysis of dicot foliage at Falkland (Dataset D, see Table A3 in Appendix A for raw abundance data), Republic (unpublished data provided by P. Wilf and K.R. Johnson, 2008; Passmore et al., 2002), McAbee (Archibald et al., 2010), Denver Basin, Colorado (locality DMNH 2484; rarefaction curve from Johnson et al., 2003); Green River (Bonanza River, Utah, rarefaction curve from Wilf et al., 2003), Laguna del Hunco (raw data in appendix to Wilf et al., 2005), and Río Pichileufú (rarefaction curve from Wilf et al., 2005). See Table 4.2 for details of sampling localities. McA = McAbee; LH = Laguna del Hunco; RP = Río Pichileufú, DB = Denver Basin. Note that of the four Laguna del Hunco quarries discussed in the text, only the most and the least speciose (LH-2 and LH-4 respectively) are included in the rarefaction diagram, for readability of figure.

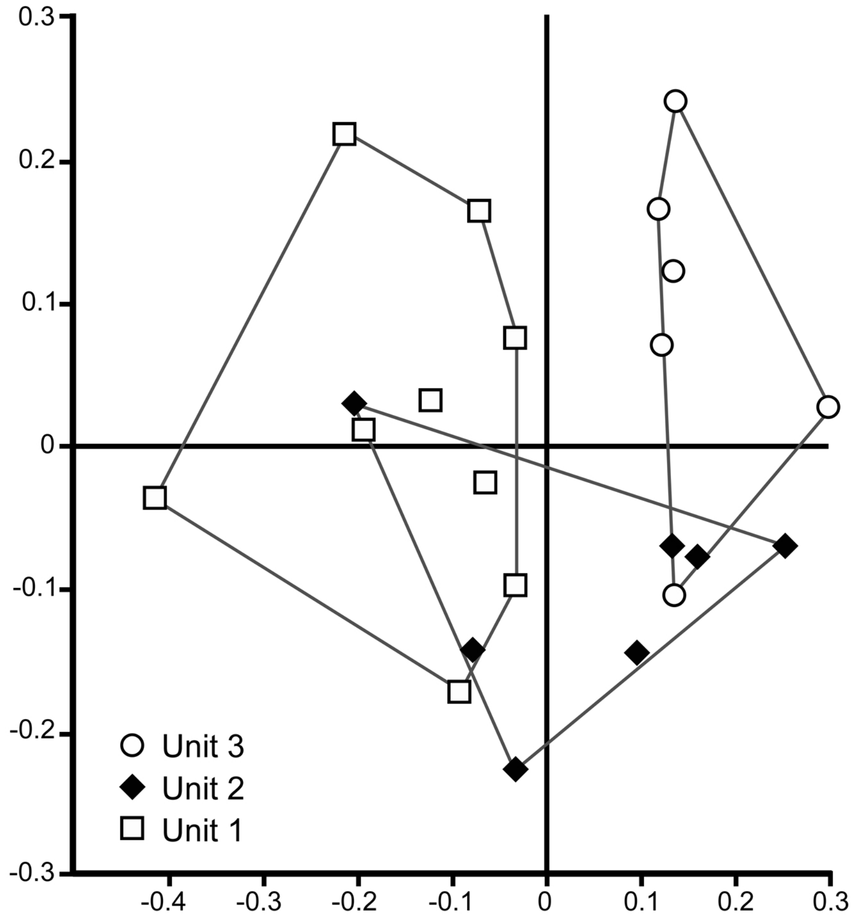

Fig 4.7. Non-metric multidimensional scaling (NMDS) ordination of quarries at the Falkland site, Dataset C. The final stress of the two dimensional plot is 0.22. The proportion of variance explained by the 2 axes is 0.52 for axis 1 and 0.17 for axis 2, giving a cumulative r^2 value of 0.69.

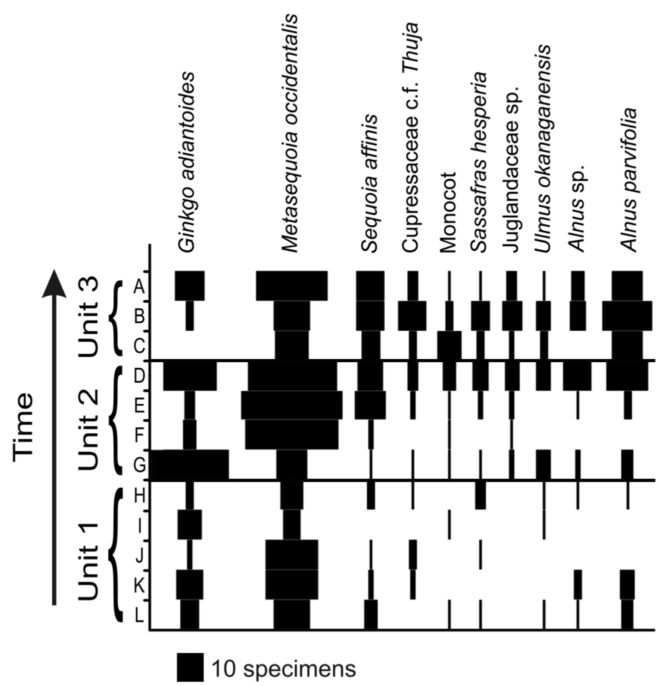

Fig. 4.8. Spindle diagram showing the abundance of the 10 most common taxa at the site in the various quarries of the three units (quarries designated A–L) from Dataset C. Correlative quarries from the two stratigraphic sections were merged.

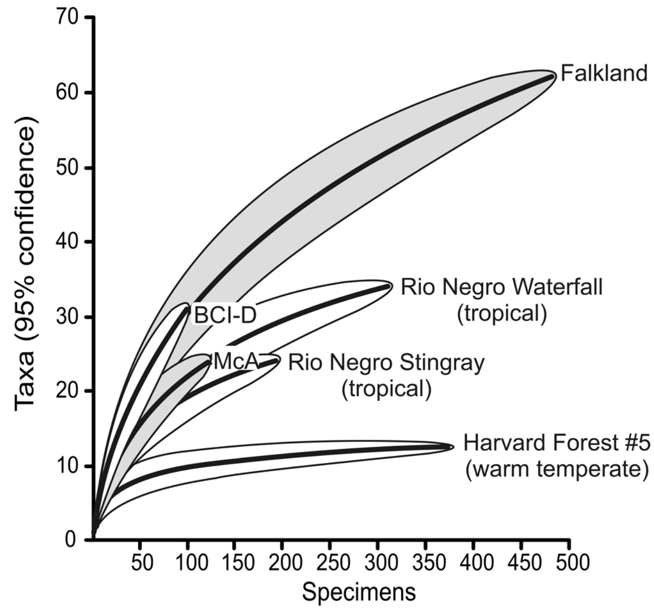

Fig. 4.9. Rarefaction analysis of early Eocene Falkland dicots (Dataset D, Table A3, Appendix A), early Eocene McAbee dicots (Archibald et al., 2010), and modern leaf litter samples from tropical rainforests in Brazil (Rio Negro Waterfall and Rio Negro Stingray) and Barro Colorado Island, Panama (Wing et al., 2009), and mid-latitude broad-leaved deciduous Harvard Forest, MA (Archibald et al., 2010). The Rio Negro, Brazil samples are grab samples from leaf mats accumulated in point bars of riverside channels, while the BCI-D sample is from a wet lake shoreline on Barro Colorado Island, Panama (Wing et al., 2009 and sources therein). McA = McAbee; BCI-D = Barro Colorado Island, Panama.

5. Paleoclimate reconstruction of the early Eocene Falkland locality, Okanagan Highlands, Canada – a comparison of physiognomic and floristic approaches[4]

Abstract: Land plants provide one of the best sources of evidence for reconstructing terrestrial paleoclimate conditions in the geological past. Climate is a major factor controlling the biogeographic distribution of plants, and aspects of leaf morphology – notably, leaf size, shape, and margin type – are influenced by and therefore reflective of the regional climate. Here we apply a range of techniques for using paleobotanical evidence to reconstruct paleoclimate of an early Eocene fossil locality in the Okanagan Highlands of British Columbia, Canada. Physiognomic techniques include leaf margin analysis (LMA), leaf area analysis (LAA), and the Climate Leaf Analysis Multivariate Program (CLAMP) that correlate aspects of leaf morphology with various climate parameters. In addition, we apply the coexistence approach (CA) which uses the climate tolerances of modern plants to identify the climate envelope in which all (or most) of the nearest living relatives (NLRs) of fossil taxa could co-exist. Overall, the different methods give reasonable and broadly consistent results, with an identifiable zone of overlap in the paleoclimate estimates. Leaf margin analysis gives the coolest climate signal of all the methods, although the upper error ranges of the warmest LMA estimates overlap with estimates from CLAMP and the coexistence approach. Mean annual temperature may be underestimated using LMA due to a bias towards toothed-margin taxa in wet-site environments, as well as other environmental factors. The results from the coexistence approach and CLAMP are in good agreement, with CA giving somewhat wider intervals that encompass the CLAMP estimates for mean annual temperature (MAT), cold month mean temperature (CMMT), warm month mean temperature (WMMT), and mean annual precipitation (MAP). Leaf margin analysis and CLAMP both indicate a trend towards declining temperature over time, with the trend more pronounced in the LMA results. The zone of overlap for the different techniques applied in this study likely provides the best estimate of paleoclimate for the Falkland site. This would place MAT at ~10.5°C, CMMT at 2.3–6.3°C, WMMT at 20.2–23.7°C, and minimum MAP estimate of 82–120 cm/year.

[4] This paper is written in GSA style. Coauthors are David R. Greenwood (Brandon University) and James F. Basinger (University of Saskatchewan).

5.1 INTRODUCTION

The early Eocene was the warmest period of the Cenozoic, based on both marine and terrestrial temperature proxies (Wing et al., 1991; Wing and Greenwood, 1993; Wolfe, 1994; Greenwood and Wing, 1995; Zachos et al., 2001, 2008). Marine records of $\delta^{18}O$ from foraminifera suggest that the acme of warmth occurred at ~52 Ma, whereas paleobotanical proxies indicate that peak levels persisted until ~50 Ma (Wing et al., 1991). The interval from 53 to 50 Ma is known as the Early Eocene Climatic Optimum (EECO) (Zachos et al., 2001, 2008). Frostless conditions likely prevailed in the continental interior and coastal areas of western North America through to the middle Eocene (Wing and Greenwood, 1993; Wolfe, 1994; Greenwood and Wing 1995).

Various factors have been proposed to explain the warm, equable conditions of the early Eocene. Greenhouse gas concentrations were likely high at this time (Sewall and Sloan, 2001), although various proxies have given different estimates of atmospheric carbon dioxide for the early Eocene, from near modern-day levels to an order to magnitude greater (Royer, 2006; Smith et al., 2010). High precipitation values in the Eocene may have been an important factor in maintaining warm, equable conditions, since water vapour is an important greenhouse gas and plays a major role in atmospheric heat transfer (Wilf et al., 1998; Greenwood et al., 2010). Sewall and Sloan (2001) suggested that a positive phase of the modern Arctic Oscillation may have caused persistent Arctic cyclonic conditions in the early Paleogene, resulting in a prolonged low pressure system over the Arctic and a corresponding increase in westerly winds at mid-latitudes that would have brought moist, warm marine air over continental areas of North America. The EECO represents the culmination of a longer-term pronounced warming trend in paleoclimate that began in the mid-Paleocene (~59 Ma), rather than a brief aberration as in the case of the Paleocene-Eocene Thermal Maximum (PETM), and was preceded by various tectonically-driven events such as North Atlantic rift volcanism that altered key global climate boundary conditions (Zachos et al., 2001).

Paleoclimate estimates of sea surface temperatures are generally derived geochemical proxies; however, estimates of terrestrial paleoclimate are more difficult to establish, as climate parameters are more complex, and there are fewer available proxies (Wing and Greenwood, 1993). Land plants provide some of the best evidence for terrestrial paleoclimate, as they are fixed in space and actively process the atmosphere through photosynthesis (Spicer et al., 2004, 2009). Climate is a major factor controlling biogeographic distribution of plants, and aspects of leaf morphology – notably, leaf shape, size, and margin type – are influenced by and therefore reflective of the regional climate (Wolfe, 1971, 1979; Wing and Greenwood, 1993). Several different techniques have been developed to reconstruct terrestrial paleoclimate parameters from fossil floras. These can be placed in two broad categories: floristic (sometimes called nearest living relative, or NLR) and physiognomic approaches.

Floristic approaches use the modern-day climatic tolerances of the nearest living relatives of fossil plants to infer climate conditions in the geological past. In contrast, physiognomic approaches are taxon-independent, and rely instead on observed correlations between various aspects of leaf architecture in woody dicots and climate parameters (Wolfe, 1971, 1993, 1995; Spicer, 1989; Wolfe and Spicer, 1999). The underlying principal is that over time there has been selection for those features of leaf morphology that confer maximum advantage in terms of balancing the needs of photosynthetic uptake, water loss, and energy expenditure on leaf structure (Wolfe and Spicer, 1999). Therefore, land plants growing under certain types of environmental conditions tend to develop similar morphologies despite taxonomic differences in floral assemblages of different geographic areas (Wolfe, 1993, 1995; Wolfe and Spicer, 1999).

Although certain workers have championed one or another of these approaches (for a review, see Greenwood 2007), there is a growing recognition of the benefits of applying a variety of techniques to the analysis of a fossil flora. Combining floristic and physiognomic approaches to estimating paleoclimate from fossil floras has been flagged as a key area for future research (DeVore and Pigg, 2010). Floristic approaches make use of elements of the flora that are not used in physiognomic techniques (conifers, ferns, reproductive structures, pollen, etc.) and therefore can provide a semi-independent cross check on physiognomic estimates (Uhl et al., 2003).

The purpose of this study is to compare results from a range of techniques for using paleobotanical evidence to reconstruct paleoclimate as applied to an early Eocene fossil locality in the Okanagan Highlands of British Columbia, Canada (Fig. 5.1). The fossil floras of the Okanagan Highlands reflect relatively cool temperatures for the early Eocene, due to their upland position in the Eocene landscape with paleoelevation estimated at ≥1–3 km (Wolfe, 1994; Tribe, 2005; Smith et al., 2009). The Falkland flora has been collected using an unbiased census approach across three informal units established on the basis of lithologic and facies changes in the outcrop (Smith et al., 2009). This approach allows for an examination of within-site trends in paleoclimate that complements earlier work on the stomatal frequency of *Ginkgo* as a proxy for paleoatmospheric carbon dioxide (Smith et al., 2010), and an assessment of changes over time in the plant community composition at the site (Chapter 4).

5.2 BACKGROUND

5.2.1 Physiognomic Techniques

The application of physiognomic approaches requires that, at minimum, specimens from a fossil flora be segregated into discrete morphotypes, informal taxonomic categories that ideally correspond to species, but without the necessity of taxonomic assignment (Johnson and Ellis, 2002; Peppe et al., 2008; Ellis et al., 2009). In this way, analysis of a fossil flora for paleoclimate information can proceed before a systematic treatment is completed, and does not require that specimens be assigned to species or formally described. However, physiognomic approaches cannot be completely divorced from taxonomy, as the sorting of specimens into morphotypes requires some knowledge of which leaf features are taxonomically informative, and which are variable, in order for the morphotypes to cohesively reflect species-level organization (Uhl et al., 2003). The splitting or lumping of taxa can have an impact on paleoclimate estimates derived from physiognomic approaches, although this is less of a concern in relatively speciose assemblages (>30 taxa) (Wolfe, 1971; *cf*. Boyd, 1994).

Commonly used physiognomic techniques include leaf margin analysis (LMA), leaf area analysis (LAA), and the Climate Leaf Analysis Multivariate Program (CLAMP). These techniques have the benefit of providing quantitative estimates of paleoclimate that are less dependent on, though not completely free from, subjective assessments by individual workers. Quantitative estimates are more easily integrated with results from other paleoclimate proxies, thereby increasing their utility for developing, testing and refining global circulation models.

5.2.1.1 Leaf Margin Analysis

Leaf margin analysis (LMA) is based on the observed positive correlation between mean annual temperature (MAT) and the proportion of woody dicot taxa that are entire-margined (Bailey and Sinnott, 1915, 1916; Wolfe, 1971, 1979; Wing and Greenwood, 1993; Wilf, 1997; Wolfe and Spicer, 1999). This relationship was documented graphically by Wolfe (1979) for mesic forests in East Asia, and later quantified by Wing and Greenwood (1993) into the first of many regression equations that can be applied to fossil floras to estimate MAT (Table 5.1, eq. 5.1). Although the original equation published by Wing and Greenwood (1993) based on the data of Wolfe (1979) continues to be applied, various workers have developed regionally-based LMA equations for floras in East Asia and North America (Table 5.1; Wilf, 1997; Kowalski and Dilcher, 2003; Miller et al., 2006; Su et al., 2010), South America (Gregory-Wodzicki, 2000), Australia (Greenwood et al., 2004) and Europe (Traiser et al., 2005). Some of these equations are based on field-sampled data, while others are derived from published floral lists, or synthetic lists based on plant range distribution maps.

The physiological basis of the leaf margin-MAT relationship likely encompasses a range of factors relating to water stress, gas exchange and photosynthesis (Yang et al., 2007). Royer and Wilf (2006) suggested that toothed leaves have an advantage in colder climates dominated by deciduous taxa. Leaf teeth provide precocious sites for photosynthesis early in the growing season when new leaves are being established in open conditions, and thus are advantageous in situations where growing season is limited by warmth or light (Baker-Brosh and Peet, 1997; Royer and Wilf, 2006; Royer et al., 2009). Teeth are also major sites of water loss via transpiration, and therefore this adaptive advantage may be outweighed by water stress in dry regions, reflected in the tendency towards increased proportion of entire margins in arid environments (Bailey and Sinnott, 1915, 1916; Wolfe, 1993). In areas where water availability is not a limiting factor (i.e. mesic to humid conditions) the LMA relationship is generally linear and well-constrained, and shows generally good agreement between East Asia, the Americas, and Europe (Gregory-Wodzicki, 2000; Kowalski, 2002; Greenwood, 2005; Spicer et al., 2004; Traiser et al., 2005; Yang et al., 2007; Su et al., 2010), with studies from Australia demonstrating a slightly different relationship (Greenwood et al., 2004; Royer et al., 2009).

Wilf (1997) made a significant contribution to the development of the LMA technique by demonstrating the robustness of the leaf margin-MAT correlation using examples from modern floras in North and South America, and proposing an equation for calculating the binomial sampling error of MAT estimates, with the caveat that a minimum error of 2°C should be adopted in cases where the statistical error is calculated at <2°C. Miller et al. (2006) further investigated the factors surrounding uncertainty in the LMA equation, noting that binomial data will often be overdispersed, showing variation greater than that predicted by the binomial sampling error. They proposed a new equation for calculating LMA error that incorporates a factor for the overdispersion of data, in additional to binomial sampling error.

Kowalski and Dilcher (2003) demonstrated that LMA may underestimate MAT by 5–10°C for sites in low-lying wet-soil environments, such as swamps, floodplains, and lakeshores, due to the tendency for toothed-margined leaves to predominate in these types of settings (Burnham et al., 2001; Greenwood, 2005; Royer et al., 2009). This is significant as fossil assemblages are typically preserved in edaphically wet and low-lying environments (Kowalski and Dilcher, 2003; Royer et al., 2009). Kowalski and Dilcher (2003) proposed a new LMA equation (Table 5.1, eq. 5.5) to correct for the wet-site bias, although based on rather a small number of sites (10) taken in part from the CLAMP dataset supplemented by new collections in wet-site environments. Miller et al. (2006) also recalculated the LMA equation (Table 5.1, eq. 5.6) using a subset of data published by Wolfe (1993) and Wilf (1997), focusing on lowland sites in North and Central America.

Recent efforts towards recalibrating the LMA equation have employed the use of "synthetic floras" (Traiser et al., 2005; Adams et al., 2008). This approach divides broad geographical areas into grid cells, and plots species range maps over these cells to derive synthetic "local" floras from which the proportion of entire-margined taxa can be calculated and correlated with climate data. There is some debate over whether field-collected samples, published floral lists, or synthetic floras provide the best data for LMA equations. On one hand, field-collected samples best mimic the scope of fossil assemblages, and the relationship of the vegetation to depositional settings and local climate can be directly assessed (Dolph and Dilcher, 1979; Wolfe, 1993, 1995). On the other hand, floral lists and synthetic floras provide a broader range of data, and overcome the challenge of locating suitable sites of undisturbed vegetation in close proximity to weather stations, and the non-random effects of sampling a heterogeneous landscape (Wilf, 1997; Adams et al., 2008). New developments suggest that it may be possible to combine gridded climate data with field collections of plant material, in order to overcome the necessity of finding undisturbed vegetation in close proximity to weather stations (Spicer et al., 2009).

The advantage of LMA is that it is simple to compute, avoids error in scoring ambiguous traits used in CLAMP (see below), and has been shown to be at least as precise as techniques incorporating multiple leaf characters (Wilf, 1997; Wiemann et al., 1998; Gregory-Wodzicki, 2000; Kowalski, 2002). The leaf margin-MAT relationship has also been convincingly validated for many – although not all – regions of the world. However, it has been criticized for returning only a single climate parameter (MAT) in comparison to multivariate approaches, and for reducing plant-environment interactions from a complex set of adaptational compromises to a simplistic one-to-one relationship (Wolfe, 1994; Wolfe and Spicer, 1999; Spicer et al., 2005; Yang et al., 2007). The potential for underestimating paleoclimate due to the wet-site bias towards toothed-leaves also remains a concern with the available datasets and equations.

5.2.1.2 Leaf Area Analysis

Leaf size has been shown to have a positive correlation with precipitation (Spicer, 1989; Wiemann et al., 1998; Wilf et al., 1998; Jacobs, 1999), although this finding is not universal, and leaf size has also been correlated with other climate factors such as MAT in some settings (Dolph and Dilcher, 1979; Greenwood, 1992). The benefit of increased carbon uptake through increased photosynthetic activity in larger leaves comes at the cost of decreased water efficiency. In dry climates, plants cannot afford this water loss, and so tend to have smaller leaves (Wilf et al., 1998). A univariate approach known as leaf area analysis (LAA) exploits the significant positive relationship between leaf size and precipitation (Wilf et al., 1998) to predict mean annual precipitation (MAP) based on size of fossil leaves. The LAA equation is based on a predictor set of 50 modern floras spanning a wide geographic and climatic range (Wilf et al., 1998).

Taphonomic bias is an important consideration in using LAA. Leaf size tends to be underestimated in litter relative to the canopy from which it is derived, a bias that is exaggerated by fluvial transport as large leaves are preferentially lost (Spicer, 1989; Greenwood, 1992). Therefore, estimates derived from LAA should likely be considered minimum values. In addition, the large error ranges associated with LAA estimates suggest that other lines of evidence should be used to validate results (Wilf et al., 1998). Precipitation has proven to be one of the most difficult climate parameters to accurately and precisely estimate when models are tested against data in modern settings (Jacobs and Deino, 1996; Wiemann et al., 1998; Wilf et al., 1998; Jacobs, 2002).

5.2.1.3 Climate Leaf Analysis Multivariate Program (CLAMP)

Based in part on perceived deficiencies with univariate leaf margin analysis, Wolfe (1993, 1995) and colleagues (Herman and Spicer, 1997; Wolfe and Spicer, 1999; Spicer et al., 2004, 2005, 2009) developed a multivariate approach to using leaf physiognomy to estimate paleoclimate called the Climate Leaf Analysis Multivariate Program (CLAMP). The original CLAMP dataset comprised 106 vegetation samples from the northern hemisphere, primarily North America with some sites from Japan and the Caribbean. The CLAMP dataset was subsequently expanded to include additional sites from Japan and North America, as well as sites from the South Pacific and Mexico (CLAMP, 2010).

To develop the CLAMP dataset, vegetation samples from each of the modern sites were scored for 29 leaf traits relating to margin features, leaf size, shape, and apex and base configurations (later expanded to 31 by the addition of two leaf size categories) and climate data was collected from nearby weather stations. The modern samples were collected from limited geographic areas (1–5 hectares) in close proximity to weather stations, with a minimum of 20 species collected at each site (Wolfe, 1993, 1995; Wolfe and Spicer, 1999). The statistical engine of CLAMP is canonical correspondence analysis, which allows for direct ordination of vegetation samples along environmental gradients and does not assume linear relationships between variables. The full dataset includes 173 sites, while a restricted dataset of 144 sites is available that excludes a nest of subalpine outliers that were found to skew estimates for other sites (CLAMP, 2010). Development of the CLAMP database through the addition of new modern calibration sites is an ongoing effort, in order to increase the applicability of the method to a wider variety of geographic settings (Spicer et al., 2009). To apply CLAMP, fossil floras are scored in the same way as the modern samples, and are appended as passive samples to the physiognomic dataset and their resulting ordination scores are projected onto the axes for the various climate parameters to arrive at the paleoclimate estimates. Wolfe (1993, 1994, 1995) described this approach as both precise (repeatable), and accurate (valid), avoiding many of the potential pitfalls of the nearest living relative approach.

The rationale for using multiple characters to predict climate parameters is based on the contention that the relationship between leaf morphology and climate is complex, and that leaf architecture involves trade-offs between competing needs and adaptive traits (Wolfe, 1995; Wiemann et al., 1998; Wolfe and Spicer, 1999; Gregory-Wodzicki, 2000; Yang et al., 2007). For example, although moisture is most closely associated with leaf size, dryness can have secondary influence on leaf margin; similarly temperature may affect leaf size, in addition to leaf margin (Wolfe and Spicer, 1999). In addition, many of the relationships between leaf morphology and climate are non-linear in nature, and therefore not amenable to simple or multiple linear regression (Wolfe, 1995; Wolfe and Spicer, 1999). However, other workers have demonstrated that the leaf margin-MAT correlation is in fact the dominant relationship expressed in CLAMP, and suggested that climate parameters such as cold month mean temperature (CMMT) are not independently derived, but rather a byproduct of modern climate regimes (Wilf, 1997; *cf*. Spicer et al., 2004). In addition, there is some subjectivity in the assessment of CLAMP leaf traits, which can lead to differences in scoring by different workers (Wilf, 1997; Wiemann et al., 1998).

5.2.1.4 Digital Capture of Leaf Physiognomy

Some efforts have been made towards digital capture of leaf morphology (e.g. Huff et al., 2003; Kreiger et al., 2007). The rationale behind these efforts is essentially twofold. First, there is a desire to remove as much subjectivity as possible from the description of leaf architecture. As noted by Wilf (1997) and Wiemann et al. (1998) there is some ambiguity in the instructions for scoring leaves according to the CLAMP model, with the result that different workers may score a fossil (or modern) flora differently, reducing the repeatability of the method. Secondly, there is a notion that capturing continuous, rather than categorical data allows for more robust statistical tests with greater degrees of precision (Kreiger et al., 2007). It remains to be seen whether these digital approaches can be realistically applied to fossil specimens, which are often incomplete and damaged. If leaf morphology of fossil specimens can only be described at the categorical or ordinal level, then attempting to capture continuous data will confer a false precision on results. The potential benefits of the approach, however, lie in the pattern-recognition power of digital technology, and the ability to quickly analyze a suite of features for well preserved specimens.

5.2.2 Floristic Techniques

Floristic techniques, using the tolerances of modern plant taxa to infer paleoclimate, have a long history of application in paleobotanical studies. While early applications of the "nearest living relative" approach were generally qualitative and subjective in nature, they did provide a starting point for paleoclimate reconstruction, and some early workers incorporated aspects of quantitative assessment of leaf architecture to support their paleoclimate estimates (e.g. Sanborn et al., 1937; MacGinitie, 1941). Modern iterations of floristic techniques, such as the coexistence approach, have expanded the role of quantitative analysis and moved towards methods that are repeatable and transparent in order to address concerns of inter-worker subjectivity.

5.2.2.1 Coexistence Approach and Bioclimatic Analysis

The coexistence approach (CA) was developed by Mosbrugger and Utescher (1997) to identify the climate envelope in which all (or most) of the NLRs of fossil taxa could co-exist, even if they do not physically exist in the same geographic locations in modern floral distributions. In contrast, the classic NLR approach can be based on a relatively small number of "indicator" species in a fossil flora, resulting in relatively wide confidence intervals and inconsistencies between different studies depending on the choice of taxa (Mosbrugger & Schilling, 1992; Wolfe, 1971). An extensive database (PALAEOFLORA, 2010) of information about the NLRs of fossil plants and their climatic tolerances has been developed to facilitate the application of CA.

The coexistence interval is established by the warmest minimum and coolest maximum of a temperature parameter, and the wettest minimum and driest maximum of a precipitation value from across the range of climate tolerances of identified NLRs. In this approach, it is possible to exclude taxa that are outliers to the majority climate overlap, usually representing relictual species that have significantly restricted ranges in modern environments (Mosbrugger and Utescher, 1997; Uhl et al., 2003; Yang et al., 2007). Although this introduces some degree of subjectivity in selecting taxa for exclusion, these taxa are often easily identified by monotypic status (e.g. *Ginkgo biloba*, *Sequoia sempervirens*, *Glyptostrobus pensilis*) and the decision can be made at the outset of the analysis to exclude monotypic taxa. Greenwood et al. (2005, 2010) introduced a slightly modified version of CA called bioclimatic analysis, which uses the 10th and 90th percentiles of climate data as upper and lower bounds of the coexistence intervals as a way to analytically, rather than subjectively, exclude outliers.

The potential sources of error in using CA are explicitly outlined in the original description of the technique (Mosbrugger and Utescher, 1997), and are issues that affect any variation of the floristic approach. Specifically, error may arise from the incorrect identification of fossil taxa; incorrect or inappropriate choice of NLR; the assumption that the climatic tolerances of the fossil taxon are the same as those of the NLR; the assumption that the modern distributions of plant taxa reflect the full range of their climate tolerances; and inadequacy of data on modern plant range distribution and climate (Mosbrugger and Schilling, 1992; Mosbrugger and Utescher, 1997; Uhl et al., 2003; DeVore and Pigg, 2010). These issues become more pronounced with increasing age of the flora, where association with modern taxa becomes tenuous (Dolph and Dilcher, 1979; Mosbrugger and Schilling, 1992; Wing and Greenwood, 1993; Mosbrugger and Utescher, 1997). The early Eocene is likely near the limits of the usefulness of floristic approaches, including CA, which are arguably better suited to application with Neogene material (Wolfe, 1993; Mosbrugger and Utescher, 1997).

The coexistence approach is ideally based on species-level identifications. However, with Paleogene material, it becomes increasingly difficult to identify appropriate NLRs at the species level, and genus-level or even family-level identifications are more realistically achieved (Mosbrugger and Utescher, 1997). This broadens the potential climate envelope for the fossil assemblage considerably (Yang et al., 2007). However, with a large enough suite of taxa, it may be possible to overcome this limitation, and in general more speciose fossil floras will give narrower coexistence intervals (Mosbrugger and Utescher, 1997). When tested against modern floras, CA generally gives robust results in that the actual climate parameters for a site fall within the coexistence intervals in most cases (Mosbrugger and Utescher, 1997). The climate parameters that have the poorest fit relate to precipitation, particularly mean annual precipitation and mean precipitation of the warmest month (Mosbrugger and Utescher, 1997).

5.2.2.2 Overlapping Distribution Analysis

Yang et al. (2007) introduced overlapping distribution analysis (ODA) as an alternative approach to deriving climate estimates from present-day geographical distributions of NLRs. To use this technique, fossil taxa and their NLRs are identified, ideally to the species level. The present-day geographical distribution of the NLRs is then investigated, and the area that contains the most NLRs is chosen as the critical zone for determining climate parameters derived from meteorological stations.

Although this technique has good potential for Neogene floras, particularly in areas where there are a large number of endemic species (Yang et al., 2007), it has limited application to Paleogene floras. The difficulties in associating Paleogene taxa with modern taxa at the species level essentially precludes this approach, since genus-level associations would result in too broad an area to be useful for delimiting climate. Additionally, older floras are more likely to have modern relatives with disjunct populations due to changes in topography and continental configurations over long timescales.

5.3 MATERIALS AND METHODS

Leaf margin analysis, leaf area analysis, CLAMP, and the coexistence approach were applied to the early Eocene Falkland flora. For the physiognomic methods, the analysis was run individually for the three units established at the site in order to track changes over time, as well as for the site as a whole. In the case of CA, the analysis was only run for the whole site as there was a limited number of taxa that could be associated with identifiable NLRs (see Appendix B). In order to capture the largest dataset possible, both census-sampled and biased-collection specimens were used in the analyses.

A summary of the available LMA equations most applicable to this study (derived from data in North America and East Asia) is provided in Table 5.1 (eqs. 5.1–5.9), and the leaf margin proportions used in the equations are in Table 5.2. MAT was calculated for all LMA equations for purposes of completeness and comparison with other studies that use one or another of these equations preferentially. However, a number of regionally-based studies have suggested that it is important to choose a predictor dataset that best matches the fossil flora in terms of regional and climate affiliation (Gregory-Wodzicki, 2000; Jacobs, 2002; Kowalski, 2002). The LMA equations deemed most applicable to this study are eqs. 5.3, 5.5, 5.8, and 5.9 (Table 5.1). Equation 5.3 is derived from the "warm-site" subset of the original CLAMP database. Wilf (1997) excluded those sites with CMMT < -2°C in order to remove the effect of cold outliers on the regression line. Equation 5.5 is the provisional LMA equation proposed by Kowalski and Dilcher (2003) to compensate for the "wet-site bias" that tends to depress MAT estimates based on LMA. Equation 5.8 is derived from the current version of the 144-site CLAMP dataset, fitting a least-squares linear regression line to the data on percentage of taxa with entire-margins and MAT. In effect, this dataset is the more current version of Wilf's "warm-site" subset derived from the original, smaller CLAMP dataset. Equations 5.3 and 5.8 are used in order to present results from relatively large and geographically diverse datasets. Equation 5.9 was derived from a subset of the current CLAMP database, selecting sites from the regions that show the closest affinities to Falkland in terms of leaf physiognomy, as determined by non-metric multidimensional scaling (see below). The regional groups included in the equation are Honshu, Japan; Yakushima, Japan; Kyushu, Japan; Eastern USA; and South USA (Table 5.3). All four of these equations are based on field-collected samples, rather than published floral lists or synthetic floras.

Leaf area analysis was applied to the Falkland flora to estimate paleoprecipitation for the site as whole, and within the three units. LAA was calculated using the equation:

$$\ln(MAP)=0.548\ MlnA+0.768 \tag{5.10}$$

where MlnA is the mean of the natural log of leaf areas for woody dicot taxa:

$$MlnA=\sum a_i p_i \tag{5.11}$$

where a_i represents the means of the seven standard leaf size categories as given in Wilf et al. (1998) and p_i represents the proportion of species in each category. Mean leaf areas may also be determined from direct measurement, but in the case of fossil specimens which are often incomplete, the leaf size categories represent a more realistic level of precision and this was the approach used in analysis of the Falkland flora. Proportions of morphotypes in each size category were determined using the same approach as in CLAMP scoring, whereby if a morphotype spanned more than one size category, it was given a partial score in each category to add up to a total of 1. The totals were then summed and divided by the number of morphotypes in the sample to calculate the proportion in each leaf size category (Table 5.2; Appendix B).

For CLAMP analysis of the Falkland site, the "Physg3brcAZ" dataset available on the CLAMP website (CLAMP, 2010) was utilized. This dataset is comprised of 144 modern vegetation samples, and excludes 29 sites that experience significant cold (the "sub-alpine nest"). The scores for the Falkland flora (Appendix B) were appended to the physiognomic dataset for analysis with the corresponding climate dataset (Met3brAZ) via canonical correspondence analysis using the software CANOCO 4.5.

In addition to running the standard CLAMP analysis, exploratory analysis of the CLAMP dataset using non-metric multidimensional scaling (NMDS) was undertaken in order to better visualize the relationships between the different sample sites and the fossil data. Results of this ordination were used to select a subset of sites from the CLAMP data for development of a new LMA equation for use with the Falkland fossil flora (Table 5.1, eq. 5.9). Prior to running the NMDS ordination, data in both the physiognomic and meteorological spreadsheets were transformed and coded by region. The meteorological data was transformed in order to place the different environmental parameters (measured in different units) on an equal footing for analysis (McCune and Grace, 2002). This was achieved through relativization by column (where each column in a dataset is a climate variable), adjusted to the standard deviation of the column variable:

$$b_{ij} = (x_{ij} - x_j)/s_j \tag{5.12}$$

where b_{ij} is the adjusted value of each cell in the data matrix, x_{ij} is the original value in row i and column j, x_j is the mean of the column, and s_j is the standard deviation of the column. This transformation has the end result of expressing each value as a z-score for the particular variable. Thus, for each climate variable, the mean of the transformed data is 0 and the standard deviation is 1.

Physiognomic data was transformed monotonically via the arcsine square-root transformation. This transformation is recommended for proportional data, as it tends to spread the ends of the distribution scale and compress the middle, thereby increasing normality (McCune and Grace, 2002). Prior to analysis, the CLAMP data was colour coded for different regional groupings of sample sites (Table 5.3). The data was analyzed through NMDS using the software PAST version 1.99 (Hammer et al., 2001) in three different runs: meteorological data only (without Falkland), physiognomic data only, and meteorological and physiognomic data combined. For the third run, the climate data for Falkland was marked as missing data; in PAST, missing data for NMDS is supported with pairwise-deletion (for each site-pair comparison, if data is missing for a particular variable at one site, the data for that variable will be deleted for the other site). Therefore, while the modern CLAMP site distance measures are calculated using overall similarity of both leaf physiognomy and meteorological data, the similarity of Falkland to the other sites is based entirely on leaf physiognomy. If the third ordination is run with the CLAMP-derived estimates for Falkland inserted, rather than marking the Falkland climate data as missing, the resulting ordination is virtually identical.

For coexistence analysis, NLRs were determined for Falkland morphotypes that were identifiable to at least the genus level (see Chapter 4). A conservative approach to identifying NLRs was taken, using genus-level data in most cases, even though some morphotypes have putative species-level NLRs identified in the literature. It is generally not advised to use species-level NLRs for coexistence analysis of Eocene and older material (T. Utescher pers. comm., 2010). It is difficult to confidently associate Paleogene and modern taxa at the species level, and even when this can be accomplished it is unlikely that species have persisted unchanged in physiology and climate preferences over long geological periods. In addition, the modern taxa that are most easily associated with fossil taxa at the species level tend to be relictual and monotypic. These taxa undoubtedly had much wider ranges in the past, and their present distribution cannot be assumed to reflect full range of climatic tolerances or thermal requirements. Relictual, monotypic, and bitypic NLR taxa were not used in this study to define the coexistence intervals, although where climate data is available (see Appendix B), it is included in the graphic output of the coexistence approach for illustration purposes only.

Three sources of information were queried for climate data for the NLRs: (1) the PALAEOFLORA (2010) database, supplemented with additional climate information provided by T. Utescher (pers. comm., 2010); (2) the *Atlas of Relations between Climatic Parameters and Distributions of Important Trees and Shrubs in North America* (Thompson et al., 1999); and (3) plant hardiness data for North America provided by Natural Resources Canada (2007). In cases where information was available from more than one source, the source with the widest range of data was used, or the information was combined to produce the widest possible intervals (see Appendix B). Climate parameters assessed using the coexistence approach are mean annual temperature (MAT), cold month mean temperature (CMMT), warm month mean temperature (WMMT), and mean annual precipitation (MAP). Some potential NLR taxa did not have climate data available at the genus level, and so were not used in the analysis.

5.4 RESULTS

The results of leaf margin analysis on the Falkland flora are presented in Table 5.1. For the site as a whole, MAT estimates derived from the four selected LMA equations (see above) range from 8.1±2.0°C to 9.5±2.2°C, with the warmest estimate derived from the Kowalski and Dilcher (2003) equation. These estimates all characterize the site as microthermal (MAT<13°C). The LMA results also show a pronounced trend towards declining MAT over time, from Units 1 to 3 (Fig. 5.2).

Leaf area analysis suggests that there is no significant change in precipitation levels over time at the Falkland site (Table 5.2), with all three units and the site as a whole giving very similar estimates of ~114 to 123 cm/yr, but with rather large error ranges. The estimates for Units 1 and 2 are almost identical, with Unit 3 appearing slightly drier; however, with the large error ranges no significant difference can be discerned between the three units. The whole-site estimate of 118 cm/yr is a mesic, or moderately most estimate, with levels similar to, for example, MAP at modern-day Vancouver (climate normals for 1971–2000 give MAP at

Vancouver International Airport as 120 cm/yr; Environment Canada, 2010), and significantly wetter than modern-day MAP in the southern interior of British Columbia (Table 5.4).

CLAMP results (Table 5.5) can be compared with the estimates from univariate leaf margin analysis and leaf area analysis. The CLAMP MAT estimate for the site as a whole is 12.5±2.0°C (assuming a minimum error of 2.0°C as per Wilf, 1997). This estimate is also microthermal, although the upper error extends into the mesothermal range. Taking error into account, this estimate overlaps with the warmest LMA estimate (eq. 5.5) in the range of 10.5–11.7°C, and the second warmest LMA estimate (eq. 5.9) in the range of 10.5–10.8°C (Fig. 5.2). The CLAMP estimates for the three units show the same trend as the LMA estimates, with evidence of cooling proceeding from Unit 1 (the oldest and warmest unit) to Unit 3 (the youngest and coolest unit). However, the difference in MAT between the three units is not as pronounced in the CLAMP results, ranging from 12.3°C in Unit 1, to 11.5°C in Unit 3, with overlapping error (Fig. 5.2). The CLAMP estimate for Unit 1 overlaps with the error ranges of all four select LMA equations; in Unit 2 the CLAMP estimate only overlaps with the two warmest LMA equations; and the CLAMP and LMA estimates for Unit 3 do not overlap at all (Fig. 5.2).

In terms of precipitation, the results from CLAMP and LAA are not as easily compared, since CLAMP provides an estimate of growing season precipitation (GSP), and LAA estimates mean annual precipitation (MAP). Growing season precipitation (GSP) is defined by Wolfe (1993) as the precipitation that falls during months with a minimum mean temperature of 10°C. In areas where the growing season is year round, GSP is equivalent to MAP. The CLAMP estimates of growing season precipitation at Falkland are lower than estimates of MAP derived from LAA; however, due to the large error ranges of these estimates, they do overlap in the range of 82–120 cm/yr. In contrast to the LAA results, CLAMP suggests that Unit 3 was the wettest, rather than the driest, of the three units, apparently from increased rainfall in the three wettest-months (with little change to precipitation in the driest months). As with LAA, however, the precipitation estimates for the three units are not statistically distinguishable in the CLAMP results. In addition, precipitation estimates from CLAMP only have moderate to low accuracies, with best results derived from mesothermal to megathermal samples with >25 species, and microthermal samples proving to be particularly problematic (Wolfe, 1993, 1995). Wolfe (1995) noted that for microthermal floras, temperature rather than precipitation tends to be the overriding influence on vegetation. Spicer et al. (2009) observed that the CLAMP values for precipitation of the three wettest and three driest months should only be used to indicate relative degree of variation in seasonable rainfall. Therefore, the significance of the difference between the LAA and CLAMP estimates of precipitation, and of the absolute difference between the estimates for the three individual units, should not be overemphasized.

Seasonal temperatures ranges as estimated by CLAMP are presented in Fig. 5.3. The WMMT temperature estimates for the three units are virtually identical, ranging from 21.4 to 22.1°C, with a site average of 21.7±2.0°C. The CMMT estimates also overlap for the three units; however, there is a more pronounced indication of cooling in the CMMT for Unit 3. This suggests that the difference in MAT is largely due to colder winter temperatures. The CMMT for the site as a whole is relatively warm at 4.3±2.0°C, particularly when compared to modern-day CMMT temperatures in the region (Table 5.4). This result suggests that the site did not experience prolonged frost, and is consistent with evidence of equable climate during the early Eocene (Wing and Greenwood, 1993; Greenwood and Wing, 1995).

The results of the NMDS ordination of the CLAMP data are presented in Figs. 5.4–5.6. These ordinations allow better visualization of the data and the relationships between Falkland and the modern sites that underlie the CLAMP estimates. The transformed meteorological data was first run on its own, in order to assess the validity of regional groupings and visualize similarities in modern sites due to climate factors. The resulting ordination (Fig. 5.4) shows cohesive regional clusters, and climatically reasonable placement of groups relative to one another. For example, the sites from Sonora and Baja California form a small, distinct cluster with closest neighbours of Puerto Rico and the American Southwest.

The transformed physiognomic data was then analyzed with NMDS, including data from Falkland (Fig. 5.5). The relative placement of the groups is generally consistent with the meteorological data, providing support for the link between climate and leaf physiognomy that underlies that CLAMP method. Based on CLAMP scores for leaf physiognomy, Falkland is most similar to a high elevation (1350 m) site from Yakusugi (Yakushima, Japan). It is interesting to note that the paleoelevation of the Falkland site has been estimated to be similar to or slightly higher than the modern elevation of 1369 m (Smith et al., 2009). A two-tiered bounding circle was imposed on the graph to capture the sites nearest to Falkland. The diameter of the circle is arbitrary, but was chosen to place the outer boundary of the circle at breaks in clusters of sites. The six sites in closest proximity to Falkland are all from Japan, primarily Honshu. The enlarged circle encompasses additional sites from Japan, along with the three sites from Maryland in the Eastern USA group.

The mean values of recorded climate data for the 17 CLAMP sites most similar in leaf physiognomy to Falkland are given in Table 5.5. The temperature parameters for this group of sites match the Falkland CLAMP results well, which is to be expected, but is reassuring in providing some confirmation of the validity of this approach to understanding the CLAMP results. The modern sites show a slightly larger mean annual range of temperatures (warmer summers and cooler winters), but overall are quite similar to Falkland in characterizing these sites as upper microthermal (MAT just below 13°C) and equable (CMMT>1°C). The fit for precipitation values is less good, with the Falkland estimates tending to be drier than the average of the sites in closest proximity in physiognomic space. In general, the precipitation parameters are the least reliable of the CLAMP estimates, especially in the case of microthermal climates (Wolfe, 1993), and the even precipitation estimates for the modern CLAMP sites are not particularly accurate when observed versus predicted values are compared. For example, the CLAMP predicted growing season precipitation for site closest to Falkland in physiognomic space (the 1350 m elevation Yakusugi site in Yakushima, Japan) is 178 cm, whereas the actual recorded value is 310 cm. Wolfe (1995) noted that above 145 cm/yr, growing season precipitation has little effect on leaf physiognomy; therefore, that value likely represents the ceiling of application for physiognomic methods to estimate paleoprecipitation.

If the physiognomic and meteorological data are combined in a single NMDS ordination, a similar picture emerges, with some minor differences (Fig. 5.6). Of the 17 sites that are closest to Falkland in the physiognomic ordination, all but one of them are within the bounding circle that includes the 24 closest sites on the combined ordination. The additional close-proximity sites in the combined ordination are from Honshu, Japan along with three sites form North Carolina (South USA group). The average recorded climate data for this group of sites is quite similar to the average of the close-proximity sites based on physiognomic data alone (Table 5.6). Taken together, these data suggest that based on leaf physiognomy, Falkland is most similar to CLAMP sites from Japan (Honshu, Kyushu, and high elevation Yakushima sites), the Eastern USA group (especially Maryland), and to a lesser extent the South USA group (especially North Carolina). These regional groups were used to construct the new LMA equation in table 5.1 (eq. 5.9).

Results of the coexistence analysis are presented in Figs. 5.7 and 5.8. The coexistence interval for MAT is 10.0–15.6°C (or 12.8±2.8°C, Fig. 5.7A). This interval encompasses the CLAMP estimate of MAT, and overlaps with all four LMA estimates from the select equations (Table 5.1) when error ranges are considered (Fig. 5.2). The lower bound of the MAT interval is set by *Koelreuteria* sp., and the upper bound is set by *Thuja* sp. (Fig. 5.7A). The identification of *Koelreuteria* sp. as an NLR is quite secure, as it is based on the presence of a reproductive structure at Falkland; however, the genus *Koelreuteria* is represented by only 3 species in the modern flora (all native to areas in East Asia), and so may have a restricted modern range distribution. *Thuja* sp. is a more tentative NLR at Falkland, as it is associated with two morphotypes that could also have *Chamaecyparis* sp. as an NLR (Chapter 4). The climate data for *Thuja* sp. is an amalgamation of genus-level data from PALAEOFLORA (2010; T. Utescher, pers. comm., 2010) plus data for two species of *Thuja* occurring in North America (*T. plicata* and *T. occidentalis*; Thompson et al., 1999; Natural Resources Canada, 2007) one of which (*T. plicata*) occurs at the modern site locality. Restricting the data to the North American occurrences of *Thuja* would lower the upper bound of the coexistence interval to 14.3°C.

The coexistence interval for CMMT is -1.4 to 8.1°C (or 3.4±4.8°C). This is a rather wide interval that does, however, encompass the site estimate from CLAMP (4.3±2.0°C). The lower bound is set by *Taxodium* sp., and the upper bound by *Equisetum* sp. (Fig. 5.8A). As with *Koelreuteria*, *Taxodium* is represented by only three species in the modern flora with ranges in the southeastern USA and Mexico. In contrast, *Equisetum* sp. is an extremely cosmopolitan genus. Climate data for *Equisetum* is based on the combined ranges of nine North American species (Natural Resources Canada, 2007), but may not be comprehensive for other geographic areas. The CMMT may be constrained by the presence of indicator taxa such as cycads and palms that are intolerant of hard frost and require a CMMT >5°C (Wing and Greenwood, 1993; Greenwood and Wing, 1995; DeVore and Pigg, 2010). Macrofossils resembling the cycad *Zamia* or *Ceratozamia* have been reported at Republic (Hopkins and Johnson, 1997; DeVore and Pigg, 2010), *Uhlia* palm macrofossils documented at the Princeton Chert (Erwin and Stockey, 1994), and *Sabal* palm pollen is present in small quantities at McAbee and Falkland, and relatively abundant at Hat Creek (Moss et al., 2005). This suggests that palms and cycads were present at some Okanagan Highlands sites, although the pollen occurrences may be explained by transport, particularly when they are found in rare quantities as is the case at Falkland. Taken together, the

CLAMP results and floristic evidence suggest that Falkland CMMT may have hovered near or just below the palm threshold line of 5°C. Palms also require MAT >10°C (Wing and Greenwood, 1995); again, Falkland appears to have been near or at this climate threshold.

The coexistence interval for WMMT is 20.2 to 26.5°C (or 23.4±3.2°). Again, this is a good fit with the CLAMP estimate of 21.7±2.0°C for the site as a whole, and also encompasses the estimates for the three units (Fig. 5.3). The lower boundary is set by *Koelreuteria* sp., and the upper boundary by *Ribes* sp. (Fig. 5.8B). Wolfe (1971) observed that *Picea* (spruce) is generally not found in areas of high summer heat and in modern floras of North America, the southern boundary of many species of *Picea* corresponds with the 21°C July isotherm (Wolfe, 1971). Data from Thompson et al. (1999) indicates that the 90th percentile of occurrences of 6 *Picea* species in North America is at WMMT of 18.3°C, although this must be extended to 24.4°C to include 100% of occurrences. Data from PALAEOFLORA (2010) extends this even further to 31.6°C, but it can be assumed that the extreme values represent a small range of occurrences. If the limitation of high summer heat extends through the fossil record, the presence of *Picea* in all three units at Falkland suggests that the WMMT was likely not much above 21°C, which fits well with the mid to lower error range estimates of CLAMP and CA.

The coexistence interval for MAP is 72 to 123 cm/yr (or 97±26 cm/yr). The lower bound is set by *Sassafras* sp. and the upper bound by *Azolla* sp. (Fig. 5.7B). The interval overlaps with the mid to lower range of the LAA estimate, the mid to upper range of the CLAMP growing season precipitation estimate. *Sassafras hesperia* is a common taxon at the fossil locality, and the conservative NLR identification of *Sassafras* sp. is quite secure. Like *Koelreuteria*, however, it is a genus represented by only three species in modern floras, one in North America (with relatively wide distribution) and two in East Asia with more limited ranges. *Azolla* sp. is rare but present, and it is a common taxon at other Okanagan Highlands localities (Greenwood et al., 2005). Both the upper and lower limits of the MAP coexistence interval are reinforced by the close range for *Quercus* section Lobatae of 70-138 cm/yr.

5.5 DISCUSSION

Results presented here update preliminary estimates of paleoclimate for the Falkland site published by Greenwood et al. (2005) and Smith et al. (2009). The Greenwood et al. (2005) estimates were based on a relatively small initial fossil collection, and on average are slightly warmer than results from this study (by ~2°C) for comparable methods (LMA eq. 5.1 and 5.3, and bioclimatic analysis) although within error limits. The estimates in Smith et al. (2009) are based on a smaller dataset, which has since been expanded through the addition of some new specimens from ongoing work, and refined through further examination of the morphotypes for taxonomic affinities (Chapter 4), leading to the revision of some early morphotypes. The initial estimates in Smith et al. (2009) are minimally revised upwards here by ~0.6°C for MAT estimates (slightly more for CMMT) and ~4 cm/yr for MAP. In addition, we provide paleoclimate estimates for the three individual units within the site, and add comparative estimates from the coexistence approach.

There is reasonably good agreement between the different methods for reconstructing paleoclimate at Falkland from the fossil flora. For MAT of the site as a whole, there is overlap between the results from the two warmest of the LMA equations, CLAMP, and the coexistence approach in the range of 10.5–10.8°C, with the other two selected LMA equations falling just outside this interval (10.1°C and 10.4°C upper error limits). When the three units are assessed individually, the CLAMP and LMA estimates overlap for Unit 1, partially overlap for Unit 2, and do not overlap at all for Unit 3. Clearly, the LMA equations give cooler MAT estimates than either CLAMP or the coexistence approach. The LMA estimates also show a much more pronounced cooling trend over time compared to CLAMP results, although the same trend is evident there.

Estimates of CMMT and WMMT are quite consistent between CLAMP and the coexistence approach, although the latter tends to give wider ranges. The CMMT coexistence interval encompasses the CLAMP estimate of 2.3–6.3°C for the site as a whole, supporting the characterization of the climate as equable. Warm month mean temperature estimates from the two methods overlap in the range of 20.2–23.7°C. Precipitation estimates overlap for leaf area analysis, CLAMP, and the coexistence interval, although this is facilitated by the fact that all methods have rather large error ranges. In general, CLAMP gives the driest estimates (in part perhaps because the CLAMP parameter is growing season precipitation, rather than mean annual precipitation), but for all three methods, there is overlap in the range of 82–120 cm/yr. The difficulties inherent in estimating MAP using any of these methods suggests that results should be regarded with some caution. However, the fact that there is a zone of overlap improves confidence.

The observation that LMA produces cooler MAT estimates than CLAMP or floristic approaches is mirrored in a number of other studies. Greenwood et al. (2005) applied both physiognomic (LMA) and bioclimatic analysis to various Okanagan Highlands floras, and found that in general the bioclimatic estimates of MAT were 3–5°C warmer than from LMA. Kennedy et al. (2002) applied LMA and CLAMP to three fossil floras (one Late Cretaceous and two Paleocene) in New Zealand. They found good agreement between the two methods for the Late Cretaceous flora, but for the Paleocene floras, the LMA estimates were significantly cooler than those derived from CLAMP. Their fossil flora MATs were microthermal, with temperatures in the range of those estimated for Falkland. It should be noted, however, that other workers have commented on the poor fit between leaf margin proportion and MAT in New Zealand, and a tendency for modern New Zealand floras to plot as outliers in the CLAMP dataset (Stranks and England, 1997; Greenwood et al., 2004; Spicer et al., 2004).

In contrast, Sun et al. (2002) found that CLAMP gave cooler estimates of MAT compared to LMA when both techniques were applied to the Middle Miocene Shanwang flora in China. On average, CLAMP estimates were ~3.5°C lower than LMA estimates. A later analysis of the same flora using the coexistence approach (Liang et al., 2003) resulted in higher estimates of MAT compared to the physiognomic approaches. Uhl et al. (2003) compared results from LMA and the coexistence approach applied to two fossil floras in Germany, one Miocene and one Oligocene. They found that both approaches gave reasonable and broadly consistent results when error ranges were taken into account. Mosbrugger and Utescher (1997) compared results from CLAMP and the coexistence approach for a Neogene flora from the Lower Rhine Embayment in Germany, and found that the two techniques displayed similar trends in climate, but that the CLAMP estimates were consistently lower than those of the coexistence approach by about 5°C.

There are several factors that could potentially account for the differences in results obtained from the methods discussed here. These factors include statistical artifacts of the calculations, the ability of the methods to accurately decode the underlying climate-leaf relationship, the validity and appropriateness of the modern calibration data underlying each method, biogeographic factors, and taphonomic bias. Ultimately, the estimates derived from physiognomic methods are dependent on the validity of the modern calibration datasets, and floristic approaches are dependent on the correct and appropriate identification of fossils and

NLRs, and the maintenance of climate tolerances within plant lineages. Table 5.1 demonstrates the influence of using different modern floras in the calibration of the LMA equation. The warmest LMA estimates of MAT for Falkland, and those closest to the CLAMP and CA estimates, derive from the equations based on wet-site environments and on the subset of CLAMP modern sites that were identified as most similar to Falkland in leaf physiognomy. The coolest estimate, and the one most at odds with results from the other methods, is based on the original CLAMP dataset of 106 sites that included the subalpine nest of cold sites. Wilf (1997) demonstrated that for floras with <34% entire margins, the multivariate CLAMP will give a warmer estimate than classic LMA (eq. 5.1), based on the slope and intercept of the regression equations derived from the respective datasets. However, even when based on the same dataset, LMA and CLAMP produce different estimates of MAT. This is demonstrated by the fact that LMA based on the current CLAMP dataset (144 sites) produces an estimate of MAT significantly lower than that derived from the CLAMP multivariate ordination (midpoint estimates of 8.4°C versus 12.5°C respectively). Therefore, the difference between LMA and CLAMP results is not solely due to the choice of calibration datasets, but reflects the fact that CLAMP incorporates other aspects of leaf morphology into the estimation of MAT.

Leaf margin proportion may be influenced by environmental factors other than climate. As discussed above, there is a tendency for toothed-margin taxa to predominate in wet-site environments such as swamps, floodplains, and lakeshores (Burnham et al., 2001; Kowalski and Dilcher, 2003; Greenwood, 2005; Royer et al., 2009). In addition, it has been suggested that for fossil floras above 50°N paleolatitude, a tendency towards deciduousness in response to lower light regimes in the winter may produce cooler paleoclimate estimates from physiognomic methods, due to the tendency for deciduous taxa to be toothed (Spicer, 1989; Greenwood and Wing, 1995). Disturbed vegetation often includes a high proportion of toothed-leaved species, which could result in a cooler signal from LMA (Spicer, 1989; Yang et al., 2007).

Any of these environmental factors could be applicable in the case of the Falkland flora, resulting in an underestimation of MAT by leaf margin analysis alone. Falkland was likely above 50°N paleolatitude in the early Eocene (estimated at ~54°N; Chapter 4, Table 4.2) and the site does appear to be dominated by deciduous taxa, even among gymnosperms (e.g. *Metasequoia* and *Ginkgo*). Furthermore, the fossil flora assemblage represents a lakeshore (likely "wet-site") environment, and there is evidence of repeated disturbance in the form of volcanic eruptions

(Smith et al., 2009). Therefore, low winter-light, wet-site environment, and disturbance events could have influenced leaf margin proportion. These biases may also affect CLAMP (Yang et al., 2007), although it is likely to be more pronounced in LMA due to the reliance on a single leaf trait.

Spicer et al. (2005) assessed the robustness of CLAMP climate predictions to loss of leaf characters through an empirical study whereby data from a modern vegetation sample was systematically degraded through the selective removal of leaf information from the CLAMP scoring. They found that CLAMP was most affected by loss of leaf margin information, particularly with respect to estimates of temperature. However, leaf margin is typically well preserved in leaf litter when compared to canopy samples, and there is no bias towards preferential loss of toothed versus entire margined taxa during transport (Greenwood, 1992; Burnham et al., 2001). Leaf size is more likely to be affected by taphonomic bias, due to the tendency for smaller sun leaves to predominate in fossil assemblages, and the preferential loss of large leaves through transport (Greenwood, 1992; Spicer et al., 2005). Even the process of collecting leaf macrofossils favours the recovery of small leaves, as larger leaves are more likely to be inadvertently split during collection. Spicer et al. (2005) found that CLAMP results were not significantly degraded through the loss of leaf size data, even with respect to precipitation estimates. However, leaf area analysis is likely to be more affected by this bias, as it is based entirely on that leaf character.

While both CLAMP and LMA indicate a trend towards declining MAT overtime, the amplitude of that trend is much greater in the LMA results. It is possible that LMA is more subject to taphonomic bias than CLAMP (or floristic approaches) but it is also possible that it is a more sensitive indicator of short-term climate fluctuations. Uhl et al. (2003) compared results from LMA and the coexistence approach when applied to Miocene and Oligocene floras in Germany, and found that while the CA estimates remained relatively constant over 26 stratigraphic levels at one site, the LMA estimates showed oscillations ranging from minor to significant. Leaf margin proportion can vary on a continuous basis to reflect minor shifts in temperature, whereas CA is dependent on presence or absence of certain taxa. It is unclear if the various ecological factors that can affect leaf margin proportion would have differentially impacted the three units at the Falkland site. The site likely represents a relatively short period of time (in the order of 10^3–10^4 years) and all three units would have been equally affected by winter light levels due to paleolatitude. The depositional environment does not appear to have changed dramatically over the history of the site, and while there is some fluctuation in the extent and nature of the disturbance regime, it seems likely that this factor would have most influenced Unit 2 (Smith et al., 2009), and the main drop in temperature indicated by both LMA and CLAMP appears to be in Unit 3. Therefore, while these factors may explain an overall underestimation of MAT based on the leaf margin analysis, they are unlikely to explain the trend towards a cooler paleoclimate signal in Unit 3. The CLAMP results, however, suggest that the cooling trend may have been more moderate than suggested by the LMA data.

5.6 CONCLUSIONS

Various studies have compared the results of different techniques for estimating paleoclimate when applied to modern calibration and/or fossil flora datasets (Mosbrugger and Schilling, 1992; Mosbrugger and Utescher, 1997; Wilf, 1997; Wiemann et al., 1998; Gregory-Wodzicki, 2000; Jacobs, 2002; Kowalski, 2002; Sun et al., 2002; Uhl et al., 2003; Yang et al., 2007). These studies have generally found that the available methods over or under predict climate parameters in non-systematic ways, giving no universal answer on which is the best or most appropriate method. Results seem to vary by region, and by the nature of the predictor and fossil floras in terms of sample size, climate, precipitation, seasonality, and elevation. However, where there is consistency of results from different methods, confidence is higher (Devore and Pigg, 2010).

Overall, results from the different methods applied in this study are generally consistent, or at least include an identifiable zone of overlap. LMA results clearly give the coolest signal of the methods applied. Due to the reliance on a single leaf trait, this technique is likely the most susceptible to bias arising from environmental influences such as wet-site environment, disturbance, and low-winter light, which may have favoured taxa with toothed margins. Multivariate approaches build in some buffers against extreme results arising from scoring of a single leaf trait (Spicer et al., 2005). The results from the coexistence approach are consistent with CLAMP, despite the fact that there are uncertainties surrounding the identification of NLRs for Paleogene taxa, and the necessity of using conservative, genus-level NLR identifications in most cases. Confidence in estimates derived from the coexistence approach applied to Paleogene floras would be low if viewed in isolation, but they do provide corroborating evidence for results derived from other techniques.

While it is impossible to assess the true accuracy of any of these methods as applied to the fossil record, the ordination of the CLAMP dataset shows good internal consistency in terms of regional groupings of climate and physiognomic data, and the Falkland flora is firmly situated in the physiognomic space of the dataset. The fact that Falkland is not an extreme outlier gives some confidence to its assessment via CLAMP. The zone of overlap for the different techniques applied in this study likely provides the best estimates of paleoclimate for the Falkland site. This would place MAT at ~10.5°C, CMMT at 2.3–6.3°C, WMMT at 20.2–23.7°C, and minimum MAP estimate of 82–120 cm/year. The cooling trend from Unit 1 to Unit 3 is reflected in both physiognomic techniques, although it is less pronounced in the CLAMP results, suggesting that LMA may be a more sensitive measure of climate or environmental change.

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TABLE 5.1. LMA EQUATIONS FOR NORTH AMERICA AND ASIA

Equation	Region	N	r^2	Equation author	Data sources	MAT (°C)*			
						Falkland	Unit 1	Unit 2	Unit 3
5.1. MAT=1.141+(30.6*P*)	East Asia	34	0.98	Wing and Greenwood (1993)	Wolfe (1979)	7.3±2.0	8.8±3.0	6.1±2.1	4.3±2.0
5.2. MAT=-0.266+(29.1*P*)	North America and Japan	106	0.76	Wilf (1997)	Wolfe (1993) CLAMP sites (original dataset)	5.6±2.0	7.0±2.8	4.5±2.0	2.7±2.0
5.3. MAT=3.25+(24.4*P*)	North America and Japan	74	0.84	Wilf (1997)	Wolfe (1993) CLAMP “warm sites” (original dataset)	**8.1±2.0**	**9.4±2.4**	**7.2±2.0**	**5.7±2.0**
5.4. MAT=2.24+(28.6*P*)	North, Central & South America	9	0.94	Wilf (1997)	Wilf (1997)	8.0±2.0	8.9±2.8	6.9±2.0	5.2±2.0
5.5. MAT=2.223+(36.3*P*)	North America	10	0.80	Kowalski and Dilcher (2003)	Kowalski and Dilcher (2003) & Wolfe (1993) “wet sites”	**9.5±2.2**	**11.3±3.6**	**8.1±2.5**	**5.9±2.0**
5.6. MAT=1.32+(28.99*P*)	North and Central America	84	0.91	Miller et al. (2006)	Wolfe (1993) and Wilf (1997) select low-lying sites	7.1±2.0	8.6±2.8	6.0±2.0	4.3±2.0
5.7. MAT=1.038+(27.6*P*)	China	50	0.79	Su et al. (2010)	Su et al. (2010)	6.6±2.0	7.9±2.7	5.5±2.0	3.9±2.0
5.8. MAT=3.444+(24.9*P*)	North America, Japan, S. Pacific	144	0.87	This paper†	CLAMP3Br dataset	**8.4±2.0**	**9.7±2.4**	**7.5±2.0**	**6.0±2.0**
5.9. MAT=3.979+(24.3*P*)	East USA, South USA, Japan	51	0.82	This paper	Select sites from CLAMP3Br dataset	**8.8±2.0**	**10.1±2.4**	**7.9±2.0**	**6.5±2.0**

Notes: N = number of modern vegetation sample sites in the calibration dataset.

* Error is expressed as the largest of 2°C (minimum error as suggested by Wilf, 1997) the binomial sampling error (Wilf, 1997), or the standard error as calculated by the formula in Miller et al. (2006). Results given in bold are from the LMA equations selected as most appropriate for this study.

† A slightly different linear regression from the CLAMP3B dataset was given by Gregory-Wodzicki (2000): MAT=3.53+(24.9*P*). This gives MAT estimates 0.1 higher than the equation given here. The source of the differing equations is not clear, but could be due to either rounding, or corrections made to the calibration sets since 2000.

TABLE 5.2. DATA USED FOR PALEOCLIMATE ESTIMATES

Sample	Unit 1	Unit 2	Unit 3	Whole site*
Dicot leaf specimens entire (%)†	25.0% (6/24)	16.2% (6/37)	10.2% (5/49)	20.0% (14/70)
Mean area of dicot leaves, ln (mm^2)	7.36	7.38	7.24	7.31
Estimate of precipitation (cm/yr)§	122 +53/-37	123 +53/-37	114 +49/-34	118 +51/-36

*Includes scree specimens (stratigraphic context unknown).
†Proportional values used in LMA equations in Table 5.1.
§Calculated using formula from Wilf et al. (1998); error is asymmetrical as converted from log values.

TABLE 5.3. REGIONAL GROUPING OF CLAMP DATA FOR NMDS ORDINATION

Group name	# of sites	Areas included
Pacific Northwest	19	Washington and Oregon
Eastern USA	11	New York, Pennsylvania, Maryland, Wisconsin*
American South	7	North Carolina, South Carolina, Georgia
Florida	3	Florida
American Southwest	26	Arizona, Colorado, New Mexico§
California	12	California
Baja California	5	Baja California
Sonora Desert	7	Sonora Desert
Puerto Rico	10	Puerto Rico
South Pacific	6	New Caledonia and Fiji
Yakushima, Japan	8	Yakushima, Japan
Kyushu, Japan	3	Kyushu, Japan
Hokkaido, Japan	5	Hokkaido, Japan
Honshu, Japan	22	Honshu and Shikoku Japan†
Falkland (fossil)	1	Falkland

* Although not on the eastern seaboard, the single site from Wisconsin consistently plotted within this group, and so is included here.
§ Colorado and New Mexico are each represented by a single site, and although they plot at the edge of the Arizona cluster, they do not cause a significant increase in the spread of this group.
† The single site from Shikoku Japan is included in this group.

TABLE 5.4. MODERN WEATHER DATA FOR CLIMATE STATIONS NEAR THE FALKLAND SITE

Weather Station	Location	Elevation (m)	MAT °C	MAT 1300 m* °C	CMMT °C	WMMT °C	MART °C	MAP† (cm)	GS (months)	GSP (cm)
Vernon	50°14.0' N 119°17.0' W	556.0	8.1	4.0	-4.2	19.6	23.8	41.0 30.8	~5	18.7
Westwold	50°28.2' N 119°45.0' W	609.0	6.2	2.4	-5.5	17.6	23.1	39.2 29.9	~5	19.5
Monte Lake	50°31.8' N 119°48.0' W	844.9	4.9	2.4	-6.3	15.9	22.2	50.2 36.0	~4	20.6

Notes: Climate normals for 1971-2000 from Environment Canada (2010). MAT = mean annual temperature; CMMT = cold month mean temperature; WMMT = warm month mean temperature; GS = growing season (months where the mean temperature >10°C); GSP = growing season precipitation (precipitation falling in months where the mean temperature >10°C).

*Adjusted using lapse rate of 5.5°C/km to reflect MAT at the elevation of modern Falkland fossil site.

†First line gives total MAP, second line gives MAP falling as rain only.

TABLE 5.5. CLAMP RESULTS FOR THE FALKLAND FOSSIL FLORA WITH COMPARATIVE DATA FROM SELECT MODERN CLAMP SITES

Sample	MAT (°C) ±1.2*	WMMT (°C) ±1.6	CMMT (°C) ±1.9	GS (months) ±0.7	GSP (cm) ±33.7	MMGSP (cm) ±3.7	3-Wet (cm) ±14.0	3-Dry (cm) ±9.3	RH (%) ±7.3	SH ±0.9	En ±0.3
By Unit											
Unit 3	11.5	21.6	2.2	6.9	96.5	14.9	55.2	35.3	76	8.3	30.66
Unit 2	12.1	21.4	3.6	7.0	78.6	13.3	47.9	31.7	79	9.8	31.16
Unit 1	12.3	22.1	3.6	7.2	79.2	13.6	48.7	33.3	79	9.7	31.17
Whole Site											
Falkland†	12.5	21.7	4.3	7.2	85.5	13.1	49.3	28.9	77	9.2	31.04
Modern CLAMP sites											
17 closest§	12.3	23.7	1.4	7.0	142.0	19.9	72.5	52.1	72.5	7.2	30.4
24 closest#	12.5	24.1	1.7	7.1	125.5	17.8	64.4	48.0	71.7	7.4	30.5

Notes: MAT = mean annual temperature; WMMT = warm month mean temperature; CMMT = cold month mean temperature; GS = growing season; GSP = growing season precipitation (precipitation falling in months where the mean temperature >10°C); MMGSP = mean monthly growing season precipitation; 3-Wet = precipitation in 3 wettest months; 3-Dry = precipitation in 3 driest months; RH = relative humidity; SH = specific humidity; En = enthalpy.

*Numbers in this row of the table give the standard deviations as calculated by CLAMP. Note that for temperature estimates, the minimum error should be 2°C (Wilf, 1997).

†Includes scree specimens.

§Average values for the 17 modern CLAMP sites most similar to Falkland based on leaf physiognomy, identified by NMDS (see Fig. 5.5).

#Average values for the 24 modern CLAMP sites most similar to Falkland based on combined leaf physiognomy and meteorological data, identified by NMDS (see Fig. 5.6).

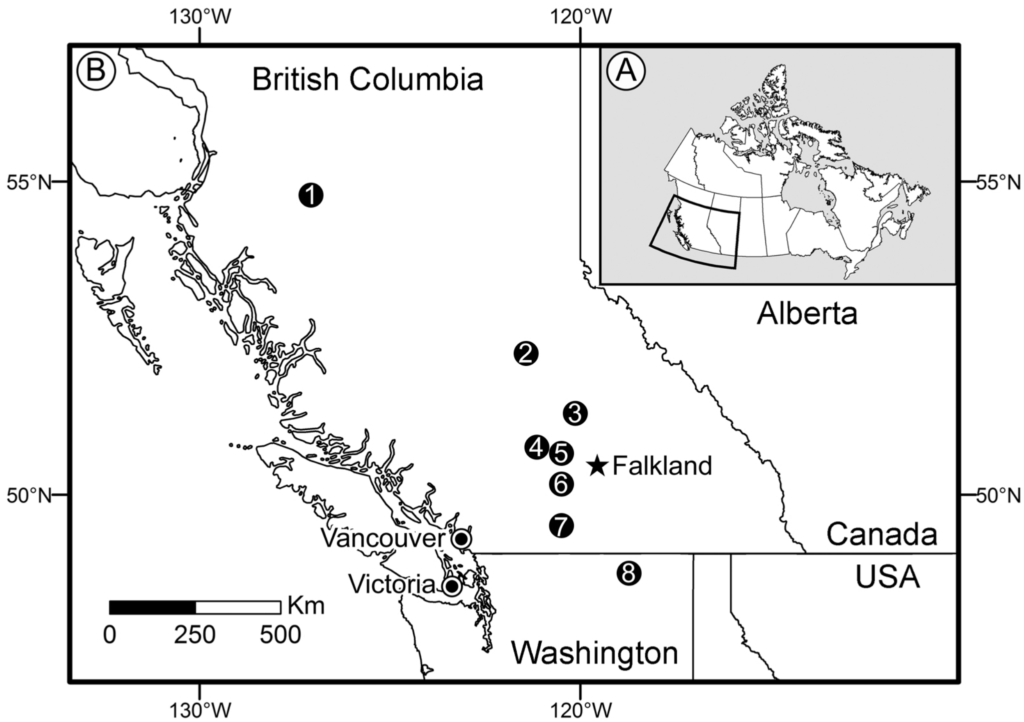


Fig. 5.1. Map showing study site location (Falkland) in British Columbia, Canada, along with other Okanagan Highlands fossil localities. A) Outline map of Canada, with GIS data provided by The Atlas of Canada (Department of Natural Resources Canada). B) Detail of portion of British Columbia, Canada and Washington, USA with Okanagan Highlands fossil localities: 1) Driftwood Canyon; 2) Horsefly; 3) Chu Chua; 4) McAbee; 5) Tranquille; 6) Quilchena; 7) Princeton (including One Mile Creek); 8) Republic, WA.

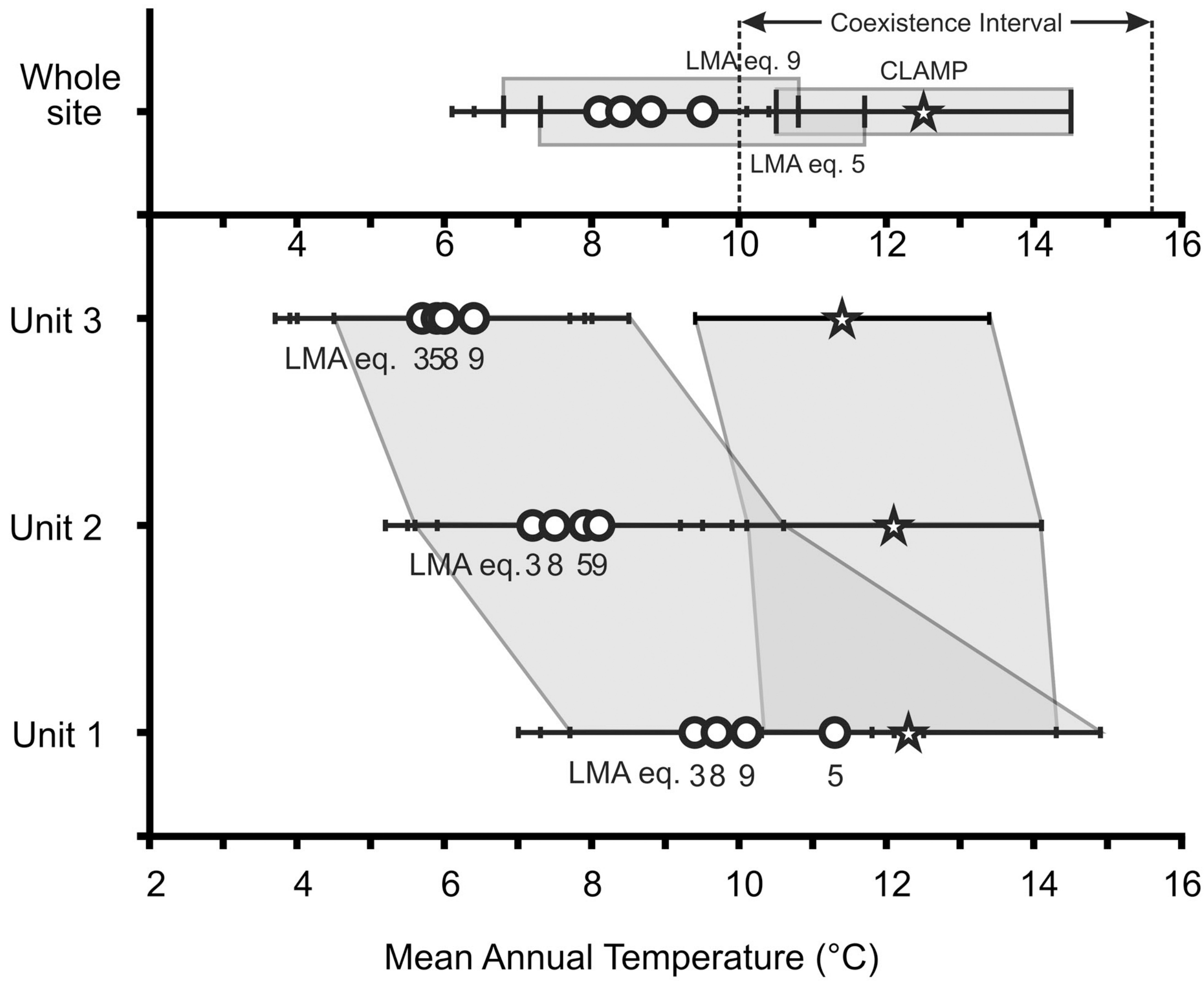


Fig. 5.2. Comparison of MAT estimates derived from LMA, CLAMP and the coexistence approach. Circles represent LMA estimates, with equation numbers from Table 5.1. Stars represent CLAMP estimates. Shaded areas for LMA results for Units 1, 2 and 3 incorporate the error limits of the warmest LMA estimate in each unit (eq. 5.5 in Units 1 and 2, and eq. 5.9 in Unit 3).

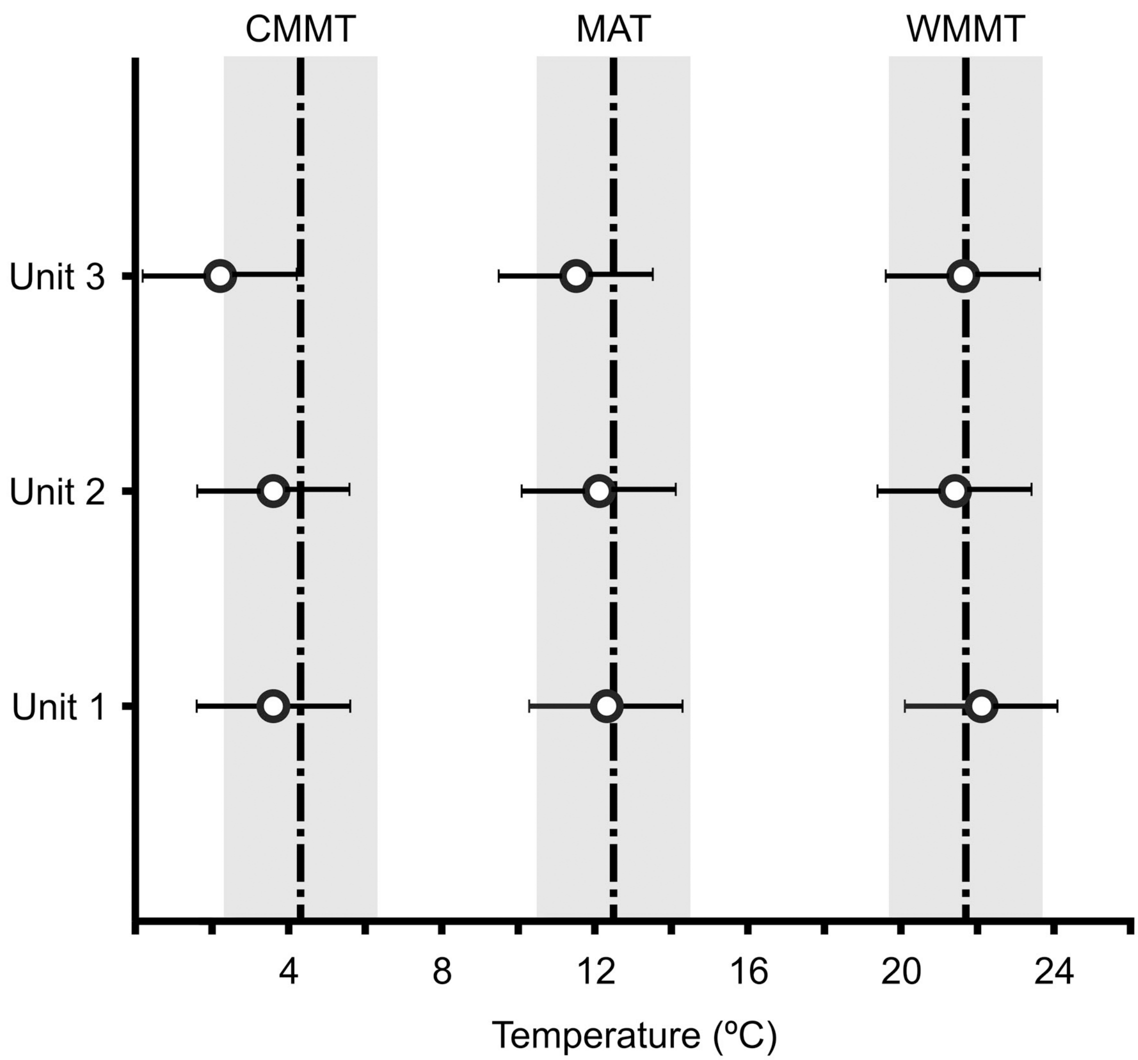


Fig. 5.3. CLAMP estimates of annual and seasonal temperatures for the Falkland site, by unit. Minimum error ranges of 2°C are adopted in all cases as per Wilf (1997). The dashed lines and shaded areas represent the whole-site estimates for each parameter.

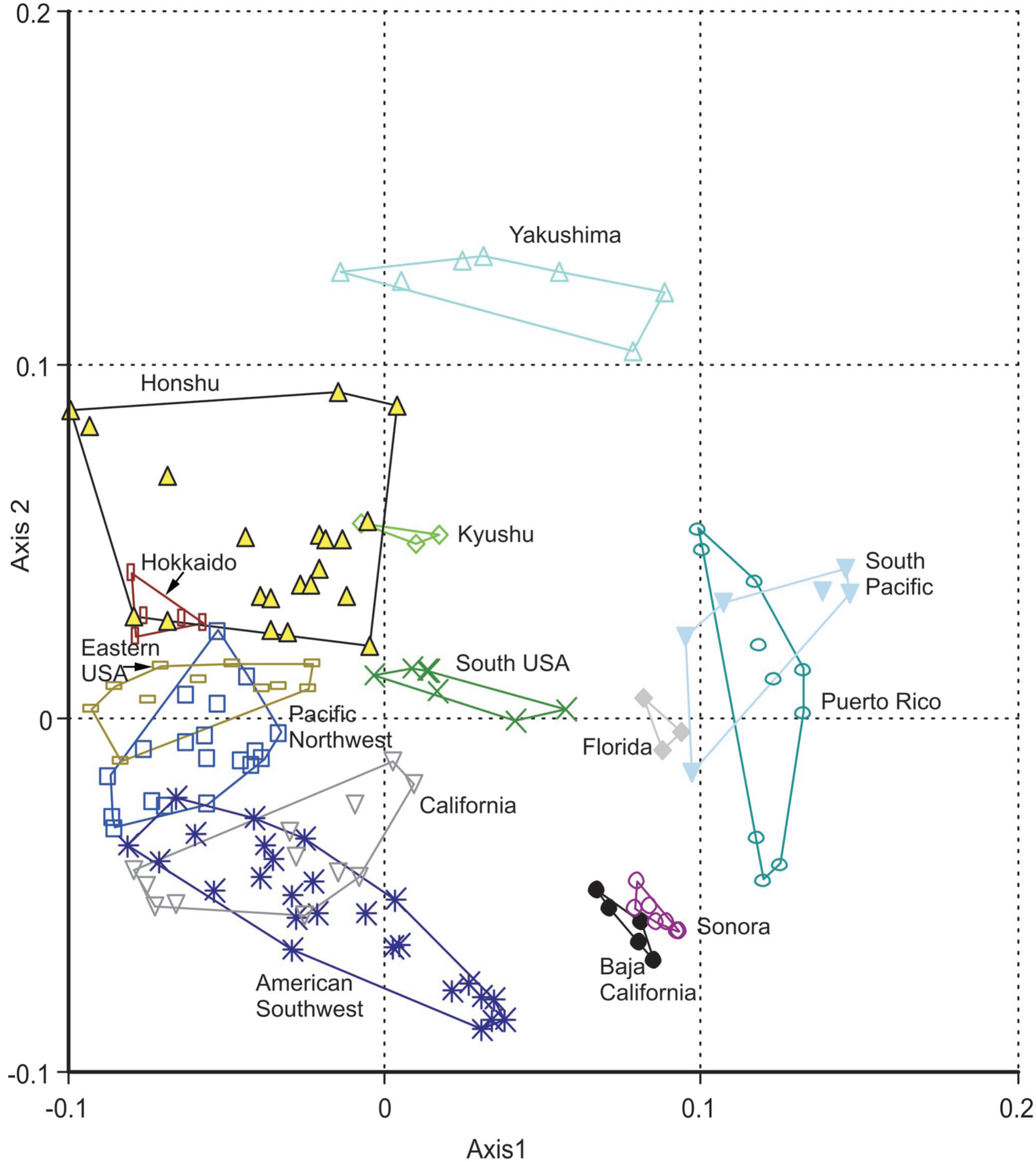


Fig. 5.4. NMDS ordination of meteorological data for CLAMP modern sites (144-site dataset). Regional groups are defined in Table 5.3. Climate data was transformed (relativized by column standard deviate) before ordination. Ordination was run using the Gower distance measure (normalized Manhattan/city block). The final stress of the ordination is 0.1117.
Axis 1 $r^2 = 0.6139$; Axis 2 $r^2 = 0.3265$.

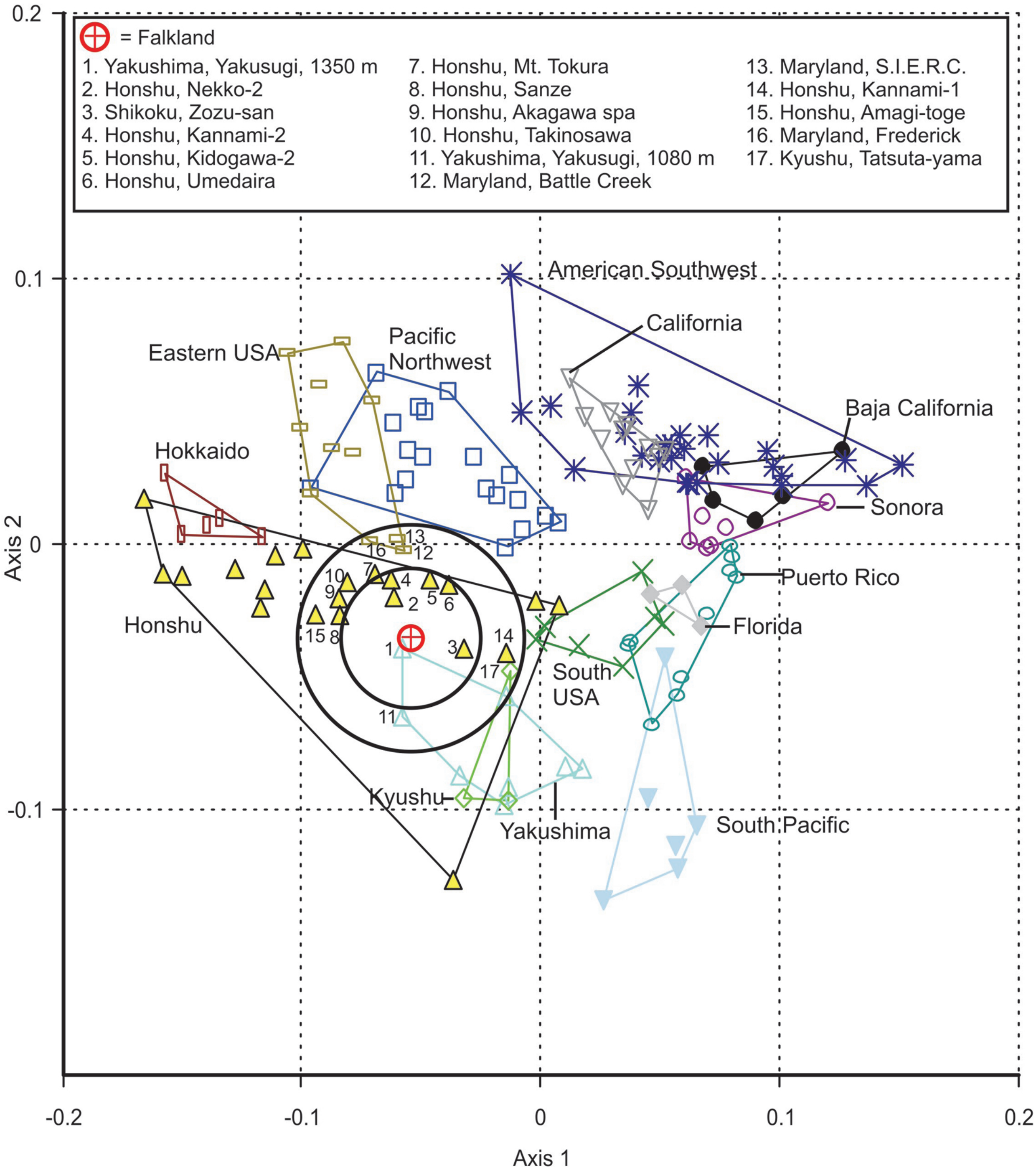


Fig. 5.5. NMDS ordination of physiognomic data for CLAMP modern sites (144-site dataset) and the Falkland fossil locality. Regional groups are defined in Table 5.3. Physiognomic data was transformed (arcsine squareroot transformation) prior to ordination. Ordination was run using the Gower distance measure. The final stress of the ordination is 0.2294. Axis 1 $r^2 = 0.6063$; Axis 2 $r^2 = 0.1148$.

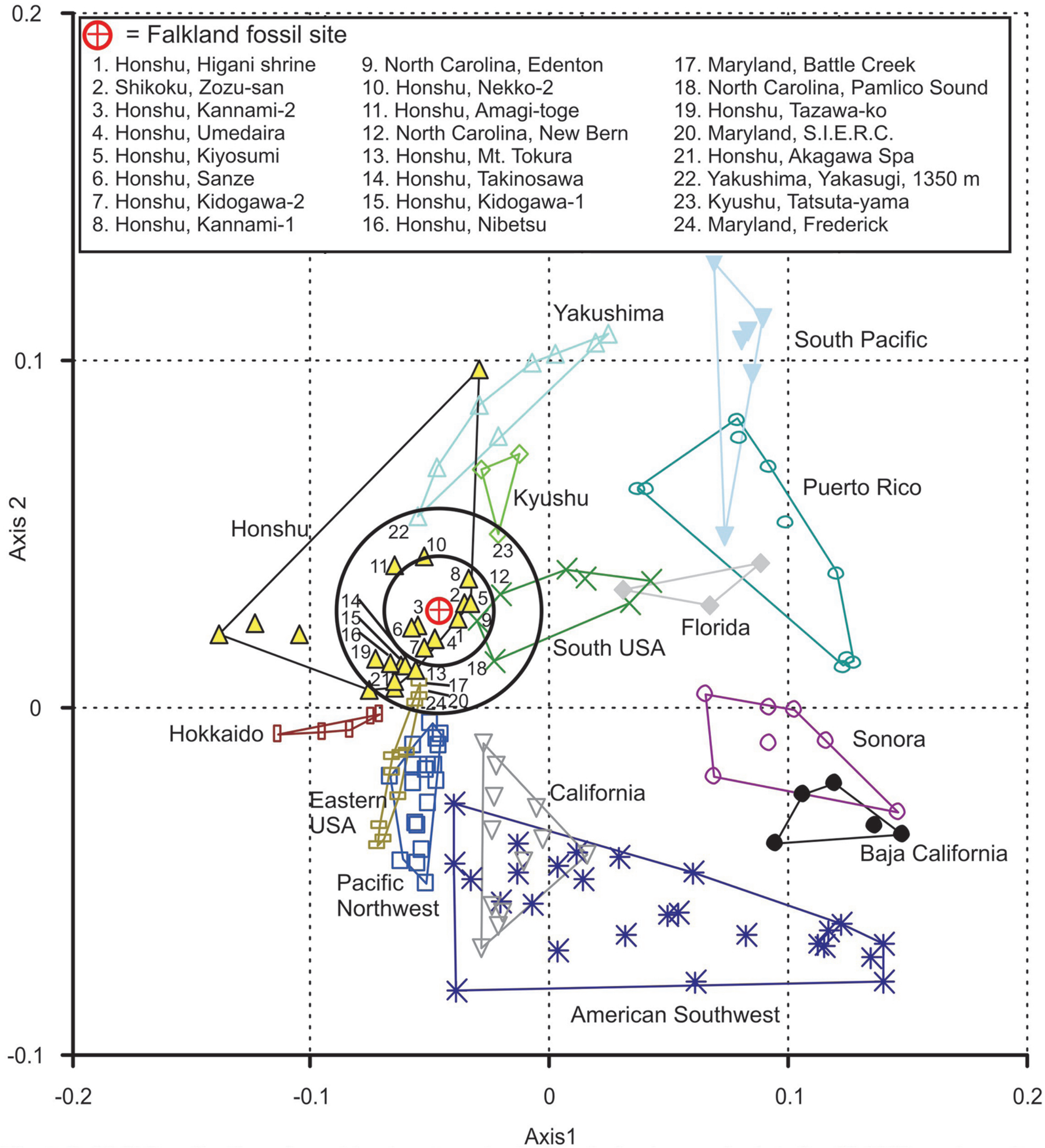


Fig. 5.6. NMDS ordination of combined meteorological and physiognomic data for CLAMP modern sites (144-site dataset) and the Falkland fossil locality. Regional groups are defined in Table 5.3. Climate data for Falkland was marked as missing data for the ordination (supported by pair-wise deletion). Ordination was run using the Gower distance measure. The final stress of the ordination is 0.1849. Axis 1 $r^2 = 0.6143$; Axis 2 $r^2 = 0.2559$.

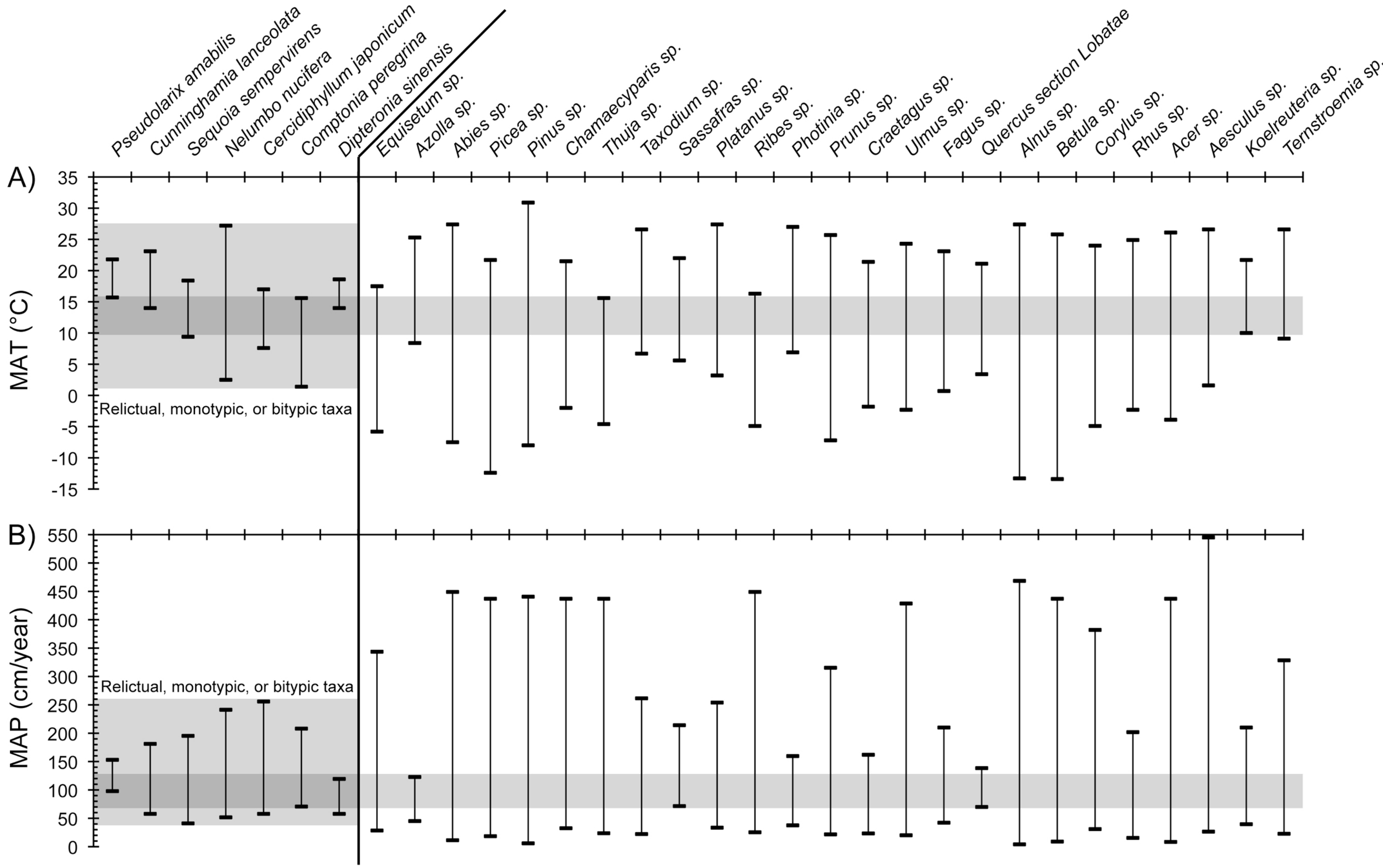


Fig. 5.7. Coexistence intervals for the Falkland flora based on climate tolerances of nearest living relatives. A) Mean annual temperature – coexistence interval 10.0 to 15.6°C. B) Mean annual precipitation – coexistence interval 72 to 123 cm/year. Relictual, monotypic or bitypic taxa not used to construct intervals.

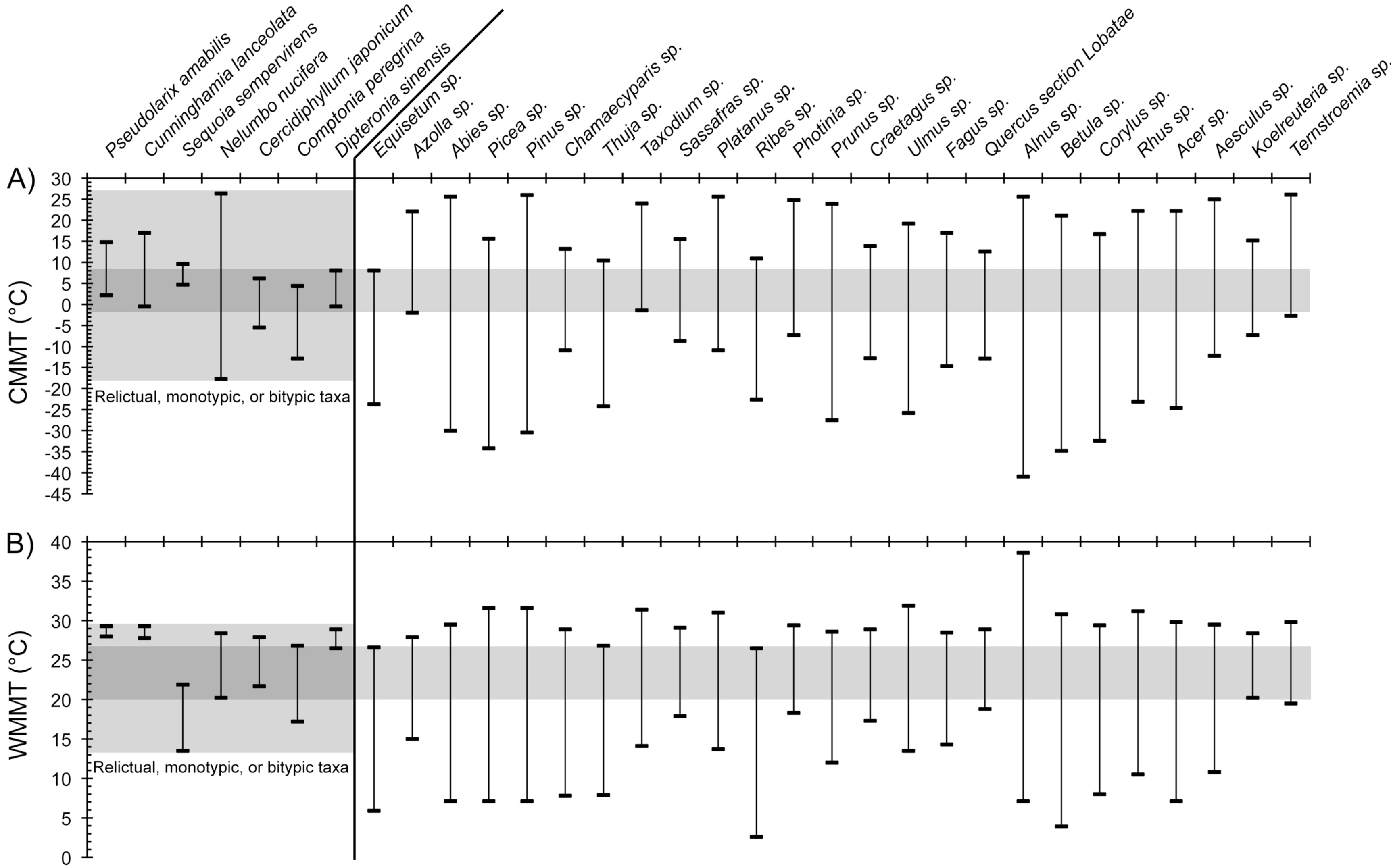


Fig. 5.8. Coexistence intervals for the Falkland flora based on climate tolerances of nearest living relatives. A) Cold month mean temperature – coexistence interval -1.4 to 8.1°C. B) Warm month mean temperature – coexistence interval 20.2 to 26.5°C. Relictual, monotypic or bitypic taxa not used to construct intervals.

6. CONCLUSIONS

The study presented in this dissertation provides an integrated assessment of the early Eocene Falkland fossil flora from a paleoecological perspective. The following numbered points summarize the major results of this study.

(1) A stratigraphic log of the exposed outcrop at the Falkland site reveals a lacustrine sequence dominated by finely laminated mudstone or shale with periodic influx of coarser material. The outcrop is subdivided into three informal units on the basis of the vertical extent of the outcrop, prominent volcanic ash layers that can be traced laterally across the site, and facies analysis.

(2) Units 1 and 3 comprise similar lithology: finely laminated, dark grey, buff-weathering mudstone or shale, indicating low-energy deposition of sediments on the lake floor. Unit 2 is characterized by a more active disturbance regime, reflected in numerous volcanic ash layers, and the brief appearance of wave ripple marks, suggesting a change in lake levels and shoreline position, followed by a distinctive fish-kill layer.

(3) Building on published floral checklists for the Okanagan Highlands fossil localities, a similarity matrix based on the Sørenson coefficient reveals a clustering of "northern" (Horsefly and Driftwood Canyon) and "southern" (Falkland, Republic, and McAbee) sites, with Sørenson coefficients of >0.70 for pairs of sites within each cluster.

(4) Based on differences in mean annual temperature (MAT) between Falkland and early Eocene sea-level localities of the Puget Group in Washington, the estimated paleoelevation of the Falkland site is 1.3±0.7 km using the global terrestrial lapse rate (TLR) of 5.5˚C/km, or 2.2±1.3 km using a regional TLR of 3.0˚C/km. Applying a second method for estimating paleoelevation based on differences in enthalpy between upland and sea-level fossil sites suggests paleoelevation of 1.6±0.9 km. This estimate is intermediate between the two estimates from the TLR approach, and slightly higher than the modern elevation of 1369 m. Thus, the paleoelevation of the site in the early Eocene is estimated to have been similar to or slightly higher than modern levels, i.e. ≥1.3 km.

(5) The stomatal frequency of fossil *Ginkgo adiantoides* at Falkland indicates that atmospheric carbon dioxide (pCO_2) was elevated during the Early Eocene Climatic Optimum (EECO) with respect to modern values. Using available transfer functions for calculating pCO_2

from stomatal index of fossil *Ginkgo*, pCO_2 is estimated at 1300 ppmV or 1430 ppmV depending on the equation used. However, due to the ceiling response demonstrated in the training set data for modern *Ginkgo,* these should be treated as semi-quantitative estimates of pCO_2 indicating levels "significantly higher than modern."

(6) This assessment is supported by evidence from the stomatal ratio method, which relates the stomatal index of a nearest living equivalent taxon to the stomatal index of a fossil pant. The stomatal ratio value is then translated to a ratio of pCO_2 relative to pre-industrial levels of ~300 ppmV. The stomatal ratio method as applied to stomatal frequencies from fossil *Ginkgo* specimens from Falkland gives minimum pCO_2 estimates of 680±50 ppmV based on stomatal index, or 780±50 ppmV based on stomatal density, supporting a conservative estimate of pCO_2 >600 ppmV.

(7) Stomatal frequencies were also calculated for specimens from each of the three units at Falkland, and suggest a decline in pCO_2 over the time period represented by this site (likely on the order of 10^3 to 10^4 years). This provides supporting evidence that climate and pCO_2 were coupled during the EECO hyperthermal.

(8) An analysis of a dataset of modern *Ginkgo biloba* leaves indicates that stomatal density is more likely to be accurately determined than stomatal index, and therefore is the preferred measure of stomatal frequency in the case of *Ginkgo*. The analysis also demonstrates a significant difference in stomatal frequency of long- and short-shoot leaves, suggesting that this factor needs to be taken into account in development of modern calibration sets for estimating pCO_2 from stomatal frequency.

(9) The Falkland flora was described in two phases. In the first phase, specimens were assigned to morphotypes, informal categories that ideally correspond to species-level organization. In total, 1561 specimens were assigned to 138 morphotypes encompassing foliage and reproductive structures. Leaves of woody dicot taxa were described in detail using standard leaf architecture terminology, and a database of morphotype records for the Falkland site was developed. The taxonomic literature was then investigated and morphotypes were assigned to formal taxa wherever possible.

(10) The Falkland site, although much more limited in both history of collection effort and extent of exposed outcrop compared to other Okanagan Highlands localities, has produced a diverse assemblage of plant fossils. Gymnosperms are dominated by taxa in Cupressaceae s.l.,

Pinaceae, and Ginkgoaceae. Ferns and fern allies are rare elements of the Falkland flora. Monocot leaves lacking diagnostic features are quite common at the Falkland site, but their taxonomic affiliation remains uncertain. The angiosperm dicot flora at Falkland is diverse, and is particularly rich in taxa from families such as Rosaceae, Betulaceae, and Sapindaceae.

(11) Unit 3, the youngest unit, demonstrates highest diversity whether measured by simple species richness or by the Shannon-Weiner index. However, in order to account for sample size (which is highest in Unit 3), rarefaction analysis was applied to assess changes in diversity over time at the site. This analysis shows that diversity is clearly higher in Unit 3 compared to Unit 1, and the rarefaction curves are beginning to diverge at >300 specimens for Units 2 and 3. At this sample size, it appears that Units 1 and 2 have similar levels of diversity.

(12) Rarefaction analysis of floral diversity was applied to Falkland dicot abundance data in conjunction with data from other early to middle Eocene sites in North and South America, where comparable analyses using rarefaction have been undertaken to reconstruct diversity. This analysis demonstrates that highest diversity is seen in Falkland and two sites from Argentina: Laguna del Hunco and Río Pichileufú, both well known as hyper-diverse early Eocene fossil localities. Falkland appears to be more diverse than Republic or McAbee for comparable sample size. This analysis demonstrates that diversity did not necessarily correlate with latitude or mean annual temperature in the Eocene world, supporting recent findings on latitudinal gradients and insect diversity indicating that equable climates in the early Eocene facilitated the development of high-diversity biotic communities even in areas with relatively low thermal insolation.

(13) Non-metric multidimensional scaling (NMDS) was employed to extract patterns in species abundance and plant community associations across the three units at the Falkland site. This analysis suggests that Unit 3 contains a distinct plant community.

(14) The patterns observed in the Falkland flora reflect a combination of factors including changing climate, declining $p\mathrm{CO}_2$, disturbance, and heterogeneity in the local landscape. Unit 2 may have marked a "threshold zone" in environmental conditions, precipitating the shift towards the plant community observed in Unit 3.

(15) Leaf margin analysis (LMA), leaf area analysis (LAA), the climate leaf multivariate program (CLAMP), and the coexistence approach (CA) were applied to the early Eocene Falkland flora to reconstruct paleoclimate. There is reasonably good agreement between results from the different methods. For mean annual temperature (MAT) of the site as a whole, there is

overlap between the results from the two warmest LMA equations, CLAMP, and the coexistence approach in the range of 10.5–10.8°C, confirming the characterization of the site as microthermal (MAT <13°C). The LMA equations give cooler MAT estimates than either CLAMP or the coexistence approach. The LMA estimates also show a much more pronounced cooling trend over time compared to CLAMP results, although the same trend is evident there, suggesting that LMA may be a more sensitive measure of climate change.

(16) Estimates of cold month mean temperature (CMMT) and warm month mean temperature (WMMT) are quite consistent from CLAMP and the coexistence approach, although the latter tends to give wider ranges. The CMMT coexistence interval encompasses the CLAMP estimate of 2.3–6.3°C for the site as a whole, supporting the characterization of the climate as equable (CMMT >0°C). WMMT estimates from the two methods overlap in the range of 20.2–23.7°C. Precipitation estimates overlap from leaf area analysis, CLAMP, and the coexistence approach in the range of 82–120 cm/yr, although this is facilitated by all three methods having rather large error ranges.

(17) NMDS analysis of the CLAMP dataset suggests that based on leaf physiognomy, Falkland is most similar to modern CLAMP sites from Japan, the eastern USA, and to a lesser extent the southeastern USA. These regional groups were used to construct a new LMA equation suitable for use with the Falkland site.

APPENDIX A:

SUPPLEMENTAL DATA FOR CHAPTER FOUR

This appendix contains information to supplement Chapter 4, "Early Eocene plant diversity and dynamics in the Falkland flora, Okanagan Highlands, British Columbia, Canada." Part I includes tabular and graphical data demonstrating the significant association between the relative abundance of angiosperm and gymnosperm fossil specimens and position in section at the Falkland site, based on Dataset B(i).

Part II contains the raw abundance data used to construct the rarefaction curves in Figures 4.5, 4.6 and 4.9. Table A2 includes specimens from Dataset B(ii), angiosperm and gymnosperm foliage morphotypes from census-sampled quarries. Table A3 includes specimens from Dataset D, dicot foliage morphotypes from census-sampled quarries.

Part III contains records from the morphotype database for the Falkland flora. This database was constructed using resources provided by the Leaf Architecture Working Group. The database template was provided as a FileMaker Pro file (courtesy of P. Wilf), and is based on the first edition of the *Manual of Leaf Architecture* (Leaf Architecture Working Group, 1999). The database template was modified to include some additional leaf architecture traits introduced in the revised *Manual of Leaf Architecture* (Ellis et al., 2009), along with some specific fields relevant to this study (e.g. distribution of morphotypes in the three units at the Falkland site). In addition, fields for CLAMP-scored traits were also added where necessary (CLAMP fields are highlighted pink in the database). Where applicable, similar morphotypes from the Republic and McAbee floras are indicated, since these two floras have been described using the same system of terminology. Republic morphotype descriptions are available on-line at http://web.burke.washington.edu/Republic/menu.php and McAbee morphotype descriptions are available at http://www.evolvingearth.org/paleocollaborator/menu.php (September, 2010).

REFERENCES

Leaf Architecture Working Group, 1999, Manual of leaf architecture - morphological description and categorization of dicotyledonous and net-veined monocotyledonous angiosperms: Washington, Smithsonian Institution, 65 p.

Ellis, B., Douglas, C.D., Hickey, L.J., Johnson, K.R., Mitchell, J.D., Wilf, P., and Wing, S.L., 2009, Manual of leaf architecture: Ithaca, New York, Cornell University Press and The New York Botanical Gardens, 190 p.

Part I. Relative abundance of angiosperms and gymnosperms over time

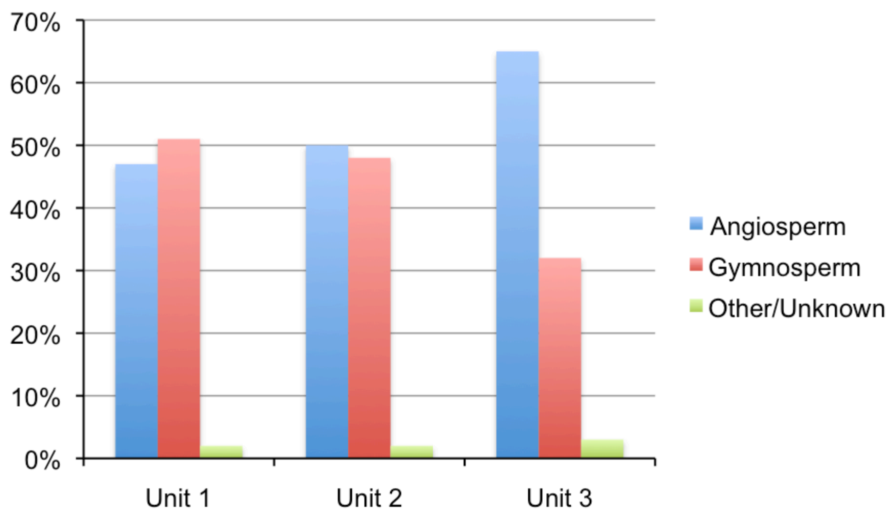
Table A1

TABLE A1. CONTINGENCY TABLE OF MAJOR TAXONOMIC GROUPS BY UNIT FROM DATASET B(i)

Position in section	Angiosperm	Gymnosperm	Other/Unknown	Total
Unit 3	459 (65%)	223 (32%)	20 (3%)	702
Unit 2	319 (50%)	308 (48%)	10 (2%)	637
Unit 1	238 (47%)	255 (51%)	11 (2%)	504
Total	1016	786	41	1843

Note: A chi-square test for independence gives the following results: $\chi^2 = 56.332$, degrees of freedom = 4, $p<0.001$.

Figure A1. Relative abundance of angiosperm and gymnosperm specimens in the three units, Dataset B (i).



Part II. Raw abundance data

Table A2

TABLE A2. RAW ABUNDANCE DATA FROM DATASET B(ii) USED FOR RAREFACTION ANALYSIS IN FIGURE 4.5

Morphotype	Unit 1	Unit 2	Unit 3	Total
FL01	0	0	1	1
FL02	0	0	1	1
FL03	9	11	17	37
FL04	58	80	20	158
FL05	6	8	17	31
FL08	2	0	0	2
FL09	0	0	1	1
FL10	0	0	1	1
FL11	0	13	23	36
FL12	116	129	94	339
FL13	0	9	16	25
FL14	0	7	6	13
FL15	0	2	0	2
FL16	0	0	1	1
FL18	0	0	1	1
FL20	15	20	24	59
FL21	7	16	10	33
FL22	0	3	7	10
FL23	18	30	52	100
FL24	3	0	1	4
FL25	1	0	0	1

Table A3

TABLE A3. RAW ABUNDANCE DATA FROM DATASET D USED FOR RAREFACTION ANALYSIS IN FIGURES 4.6 & 4.9

Morphotype	Unit 1	Unit 2	Unit 3	Total
FL01	0	0	1	1
FL02	0	0	1	1
FL03	9	11	17	37
FL08	2	0	0	2
FL09	0	0	1	1
FL10	0	0	1	1
FL11	0	13	23	36
FL13	0	9	16	25
FL14	0	7	6	13
FL15	0	2	0	2
FL16	0	0	1	1
FL18	0	0	1	1
FL20	15	20	24	59
FL21	7	16	10	33
FL22	0	3	7	10
FL23	18	30	52	100
FL24	3	0	1	4
FL25	1	0	0	1
FL26	2	0	1	3
FL28	0	0	1	1
FL29	1	2	6	9

Morphotype	Unit 1	Unit 2	Unit 3	Total
FL26	2	0	1	3
FL28	0	0	1	1
FL29	1	2	6	9
FL30	4	1	2	7
FL31	9	7	20	36
FL33	4	16	5	25
FL34	1	5	5	11
FL35	0	1	0	1
FL37	26	27	36	89
FL39	1	5	5	11
FL40	0	1	2	3
FL44	0	2	8	10
FL47	1	0	0	1
FL49	0	0	1	1
FL50	0	0	1	1
FL52	5	8	10	23
FL54	0	1	1	2
FL55	4	5	0	9
FL56	0	0	2	2
FL57	0	4	1	5
FL64	0	0	1	1
FL67	2	2	2	6
FL69	2	0	6	8
FL74	0	2	1	3
FL77	0	2	1	3
FL79	0	0	2	2
FL80	2	0	0	2
FL82	0	1	1	2
FL84	0	0	1	1
FL86	0	1	0	1
FL88	1	3	1	5
FL89	0	0	1	1
FL90	0	0	2	2
FL93	1	0	0	1
FL97	0	1	0	1
FL100	1	2	4	7
FL110	0	1	1	2
FL114	2	11	5	18
FL115	1	2	1	4
FL116	0	0	1	1
FL117	0	2	0	2
FL118	2	0	1	3
FL122	0	2	0	2
FL123	1	0	1	2
FL126	0	1	0	1
FL127	0	0	1	1
FL134	0	1	0	1
FL143	0	0	1	1
FL144	0	0	1	1
FL149	1	0	0	1
FL150	2	1	0	3
FL152	0	1	0	1
FL153	1	1	1	3
FL156	0	1	0	1
FL159	1	2	5	8
FL160	0	1	0	1
FL163	0	0	1	1
Grand Total	313	454	443	1210

Note: Table includes angiosperm and gymnosperm foliage morphotypes from census-sampled quarries.

Morphotype	Unit 1	Unit 2	Unit 3	Total
FL30	4	1	2	7
FL34	1	5	5	11
FL35	0	1	0	1
FL39	1	5	5	11
FL40	0	1	2	3
FL44	0	2	8	10
FL47	1	0	0	1
FL49	0	0	1	1
FL50	0	0	1	1
FL54	0	1	1	2
FL56	0	0	2	2
FL57	0	4	1	5
FL67	2	2	2	6
FL69	2	0	6	8
FL77	0	2	1	3
FL79	0	0	2	2
FL80	2	0	0	2
FL82	0	1	1	2
FL84	0	0	1	1
FL86	0	1	0	1
FL88	1	3	1	5
FL93	1	0	0	1
FL97	0	1	0	1
FL100	1	2	4	7
FL110	0	1	1	2
FL114	2	11	5	18
FL115	1	2	1	4
FL116	0	0	1	1
FL117	0	2	0	2
FL118	2	0	1	3
FL122	0	2	0	2
FL126	0	1	0	1
FL127	0	0	1	1
FL134	0	1	0	1
FL143	0	0	1	1
FL144	0	0	1	1
FL152	0	1	0	1
FL153	1	1	1	3
FL159	1	2	5	8
FL160	0	1	0	1
FL163	0	0	1	1
Grand Total	81	170	235	486

Note: Table includes dicot foliage morphotypes from census-sampled quarries only.

Part III (following pages). Morphotype database records for the Falkland flora

Falkland (BC) Flora	Morphotype Name	Comptonia columbiana	Morphotype #	FL001

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Myricaceae	*Comptonia*	RYS06-0001

PHOTO

Description of morphotype:

Narrow, pinnately lobed microphyll leaf. Laminar L:W ratio 4.3-6:1; laminar shape elliptic and symmetrical. Margin pinnatisect and toothed. Apex is acute and convex, base is acute and cuneate (straight). Primary venation is pinnate. Major secondaries craspedodromous. Intercostal tertiary veins irregular reticulate. Higher order venation indistinct. Leaf texture chartaceous. Tooth spacing is regular, and teeth are compound. Teeth about 2 per cm with angular sinus. Lobes are serrate with a single secondary tooth on the apical side of the main tooth. Some teeth appear to also have a smaller secondary tooth on the basal side of the main lobe. Note that CLAMP laminar size refers to individual lobes.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP034
MB048

Falkland Specimens:

RYS06-0001
RYS07-0934
RYS08-0021

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	leptophyll 1; leptophyll 2	Base Angle	acute
Laminar Shape	elliptic	Apex Angle	acute
Laminar Symmetry	symmetrical	Base Shape	cuneate
L:W Ratio	4.3-6:1	Apex Shape	convex
Base Symmetry	symmetrical	Margin Type	serrate
		Lobation	pinnately

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	not visible
2° Vein Category	craspedodromous	Length	not visible
2° Vein Spacing	not visible	Proximal course	not visible
2° Vein Angle	not visible	Distal course	not visible
2° attachment	excurrent	Vein frequency	not visible

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	not visible
3° Vein Course	not applicable	Epimedial3° proximal course	not visible
3° Angle to 1°	not applicable	Epimedial3° distal course	not visible
3° Vein Angle Variability	not applicable	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth Round	○ yes ◉ no
Spacing	regular	Teeth Acute	◉ yes ○ no
Shape	st/cv; cc/cv; st/fl; cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	?Holodiscus sp.		Morphotype #	FL002
Major Plant Group: DIC	Organ Type: Leaf	Plant Family: Rosaceae	Genus: *?Holodiscus*	Type spec. #	RYS06-0341

PHOTO

Description of morphotype:

Microphyll leaf with broadly rounded crenate teeth. Texture appears membranaceous Apex angle narrowly obtuse (~90˚) and convex. Base angle is acute and concave. Primary venation pinnate. Major secondaries craspedodromous with decurrent to deflected attachment. Secondaries depart midrib at an acute angle (~25˚) and travel in a fairly straight line to the margin. Basal secondaries are longer and depart at a more acute angle. Secondaries have exmedial branches on apical side departing about 3/4 to 4/5 of the length and terminate at the superadjacent sinus. Higher order venation indistinct. Tooth spacing regular to irregular, with two orders of teeth. Teeth ~ 3/cm, shape cv/cv.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0341

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	Base Angle	acute
Laminar Shape	elliptic	Apex Angle	obtuse
Laminar Symmetry	symmetrical	Base Shape	decurrent
L:W Ratio	1.5:1	Apex Shape	convex
Base Symmetry	not visible	Margin Type	crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	smoothly decreasing towards base	Distal course	not applicable
2° attachment	deflected	Vein frequency	not applicable

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course	not visible	Epimedial3° proximal course	not visible
3° Angle to 1°	not visible	Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	◉ yes ○ no
Teeth/cm	3	Teeth Round	○ yes ◉ no
Spacing	irregular	Teeth Acute	○ yes ◉ no
Shape	cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Sassafras hesperia	Morphotype #	FL003

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Lauraceae	*Sassafras*	RYS07-0842

PHOTO

Description of morphotype:

Palmately lobed entire-margined leaf. Leaf also occurs as an unlobed form, included in this morphotype. Laminar size microphyll to mesophyll, but predominately notophyll to mesophyll. Lamina is elliptic to obovate. Apex angle is acute to obtuse and convex in shape, base angle is obtuse and concave to concavo-convex in shape. Primary venation is suprabasal actinodromous with three primary veins and simple agrophic veins. Major secondaries brochidodromous, attachment excurrent to deflected. Primary veins enter the apex of the lateral lobes while secondary veins enter sinus of lobes. Interior secondaries are present. Minor secondary course simple brochidodromous. Intersecondary veins present.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes (RP=Republic, MB=McAbee): RP048, MB075, MB085

Falkland Specimens:

RYS06-0150, RYS06-0169, RYS06-0178, RYS06-0191, RYS06-0267, RYS06-0382, RYS06-0418, RYS06-0608, RYS06-0629, RYS06-0700, RYS06-0707, RYS06-0711, RYS06-0730, RYS06-0750, RYS06-0923, RYS06-0925, RYS06-1018, RYS06-1027, RYS07-0002, RYS07-0074, RYS07-0136, RYS07-0147, RYS07-0168, RYS07-0192, RYS07-0215, RYS07-0232, RYS07-0288, RYS07-0340, RYS07-0387, RYS07-0484, RYS07-0511, RYS07-0546, RYS07-0712, RYS07-0716, RYS07-0718, RYS07-0723, RYS07-0829, RYS07-0842, RYS07-0961, RYS08-0033

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll	Petiolar Attach.	marginal	
Clamp Size	microphyll 3	mesophyll 3	Base Angle	obtuse	Apex Angle: acute to obtuse
Laminar Shape	elliptic	obovate	Base Shape	concavo-convex	concave
Laminar Symmetry	symmetrical	L:W Ratio: 1.0-1.5:1	Apex Shape	convex	
Base Symmetry	symmetrical		Margin Type	entire	Lobation: palmately; unlobed

1° to 2°

1° Vein Category	suprabasal actinodromous	Interior secondaries	present
Agrophic Veins	simple	Minor 2° course	simple brochidodromous
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	brochidodromous	Length	<50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	inconsistent	Distal course	perpendicular to subjacent secondary
2° attachment	excurrent to deflected	Vein frequency	>1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	irregular reticulate	Epimedial3°	alternate percurrent
3° Vein Course	sinuous		Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	regular polygonal reticulate
Exterior tertiary course	looped		5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth Round	◌ yes ◌ no
Spacing		Teeth Acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Ginkgo adiantoides	Morphotype #	FL004

Major Plant Group	GIN	Organ Type	Leaf	Plant Family	Ginkgoaceae	Genus	*Ginkgo*	Type spec. #	RYS07-0067

PHOTO

Description of morphotype:

Distinctive fan shaped leaves with open dichotomous venation. Laminar size microphyll to notophyll. Base shape is decurrent; apex is fan shaped with a wavy-margin. Both entire and lobed varieties found at Falkland, likely representing short and long shoot morphologies. Many specimens have extremely well-preserved cuticle. Epidermal cells on the adaxial surface display undulate anticlinal cell walls, and lack papillae and stomata. Cells over veins are elongate and rectangular, while intercostal cells are isodiametric to rectangular or polygonal. Abaxial epidermal cells are papillate, and subsidiary cells surrounding the stomata are strongly papillate, and amphicyclocytic in arrangement.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes (RP=Republic, MB=McAbee)
RP110
MB002

Falkland Specimens:

Ginkgo was found in almost all quarries at the site, with 186 specimens recorded in the full dataset.

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Monocot sp. 1	Morphotype #	FL005

Major Plant Group	MON	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0268

PHOTO

Description of morphotype:

Generally preserved as leaf fragments, long and slender, variable in width but typically 1-2 cm. Venation is parallel, with approximately 17 distinct veins in the type specimen separated by smaller parallel veinlets, no distinct midvein. Some specimens appear to taper at the base.

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee	RP296
Unit 3	☒		
Unit 2	☒		
Unit 1	☒		
Scree	☐		

Falkland Specimens:

RYS06-0006, RYS06-0161, RYS06-0213, RYS06-0239, RYS06-0249, RYS06-0263, RYS06-0268, RYS06-0276, RYS06-0282, RYS06-0333, RYS06-0364, RYS06-0453, RYS06-0731, RYS06-0795, RYS06-0804, RYS06-0848, RYS07-0108, RYS07-0133, RYS07-0208, RYS07-0273, RYS07-0274, RYS07-0326, RYS07-0359, RYS07-0441, RYS07-0456, RYS07-0548, RYS07-0577, RYS07-0758, RYS07-0812, RYS07-0823, RYS07-0872, RYS07-0905

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Betulaceae sp. 1	Morphotype #	FL006

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family	Betulaceae	Genus		Type spec. #	RYS07-0915

PHOTO

Description of morphotype:

Staminate inflorescence, narrowly elliptic in outline, approximately 3-4 mm wide and up to 5 (+) cm long. Peduncle is 5 (+) mm long and ~1.5 mm wide. Most appear to be borne singly, although one specimen (RYS07-0080) may have catkins in pairs (but attachment not preserved).

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee	
Unit 3	☒		RP102
Unit 2	☒		MB317
Unit 1	☐		
Scree	☒		

Falkland Specimens:

RYS06-0164, RYS06-0177, RYS06-0188, RYS06-0743, RYS06-0763, RYS06-0764, RYS06-0772, RYS07-0080, RYS07-0313, RYS07-0516, RYS07-0902, RYS07-0912, RYS07-0914, RYS07-0915, RYS08-0017

Leaf Architecture - Dicots Only

LEAF			
Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS		TEETH			
Areolation		# of Orders		Teeth Close	◌ yes ◌ no
F.E.V.s		Teeth/cm		Teeth round	◌ yes ◌ no
Marginal Ultimate Venation		Spacing		Teeth acute	◌ yes ◌ no
		Shape		Principal vein	
		Sinus		Termination	
		Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Cercidiphyllum sp.	Morphotype #	FL007

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Cercidiphyllaceae	Genus	*Cercidiphyllum*	Type spec. #	RYS06-0977

PHOTO

Description of morphotype:

Microphyll leaf with cordate base and crenate margin. Primary venation basal actinodromous with 5 basal veins and compound agrophic veins. Major secondaries semicraspedodromous. Interior secondaries present; minor secondary course semicraspedodromous. Tooth spacing regular, with one order of teeth; teeth about 4/cm; sinus shape angular. Tooth shapes cv/cv and cc/cv with glandular apices. NOTE: This specimen may be reassigned to Tetracentron sp. on the basis of margin and tooth type.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☐
Unit 1	☐
Scree	☒

Similar Morphotypes	
RP=Republic MB=McAbee	RP015 MB076

Falkland Specimens:

RYS06-0977

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	Base Angle	obtuse
Laminar Shape	elliptic	Apex Angle	obtuse
Laminar Symmetry	symmetrical	Base Shape	cordate
L:W Ratio	1.3:1	Apex Shape	convex
Base Symmetry	symmetrical	Margin Type	crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	present
Agrophic Veins	compound	Minor 2° course	semicraspedodromous
# of Basal Veins	5	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	irregular	Proximal course	not applicable
2° Vein Angle	smoothly decreasing towards base	Distal course	not applicable
2° attachment	deflected	Vein frequency	not applicable

3° to 5°

3° Vein Category	alternate percurrent	Epimedial3°	alternate percurrent
3° Vein Course	not applicable	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	basiflexed
3° Vein Angle Variability	inconsistent	4° Vein Category	irregular reticulate
Exterior tertiary course	terminating at margin	5° Vein Category	not visible

FINE VEINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	4	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	○ yes ◉ no
Shape	cv/cv cc/cv	Principal vein	present
Sinus	angular	Termination	distal flank of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL008

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf			RYS06-0587

PHOTO

Description of morphotype:

Microphyll to mesophyll ovate leaf. Margin unlobed and entire. Apex is acute and straight; base is obtuse and rounded. Leaf texture chartaceous to coriaceous. Primary venation suprabasal actinodromous with 3 basal veins and simple agrophic veins. Major secondaries simple brochidodromous. Interior secondaries present. Minor secondary course brochidodromous. Intersecondary veins present. Intercostal tertiary veins mixed percurrent. Exterior tertiary course looped. Quaternary vein fabric alternate percurrent. Quinternary vein fabric irregular reticulate. Areolation shows moderate development with freely ending veinlets mostly two or more branched, simple termination.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☒
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0587
RYS07-0808
RYS07-0931

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll
Clamp Size	microphyll 1	mesophyll 1
Laminar Shape	ovate	
Laminar Symmetry	symmetrical	L:W Ratio 1.3-1.5:1
Base Symmetry	symmetrical	
Petiolar Attach.	marginal	
Base Angle	obtuse	Apex Angle: acute
Base Shape	rounded	convex
Apex Shape	straight	
Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	suprabasal actinodromous
Agrophic Veins	simple
# of Basal Veins	3
2° Vein Category	brochidodromous
2° Vein Spacing	increasing toward base
2° Vein Angle	smoothly decreasing towards base
2° attachment	decurrent
Interior secondaries	present
Minor 2° course	simple brochidodromous
Inter-2° Veins	present
Length	<50% of subjacent secondary
Proximal course	parallel to major secondaries
Distal course	perpendicular to subjacent secondary
Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	mixed opp/alt	alternate percurrent
3° Vein Course	not applicable	
3° Angle to 1°	obtuse	
3° Vein Angle Variability	inconsistent	
Exterior tertiary course	looped	
Epimedial3°	mixed	
Epimedial3° proximal course	obtuse to midvein	
Epimedial3° distal course	parallel to intercostal tertiaries	
4° Vein Category	alternate percurrent	
5° Vein Category	irregular reticulate	

FV IE NI EN RS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth Round	◌ yes ◌ no
Spacing		Teeth Acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Incertae sedis					Morphotype #	FL009
Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus	
Type spec. #	RYS06-0118						

PHOTO

Description of morphotype:

Small elliptic to nearly orbicular leaf with asymmetrical lamina. Base may also be asymmetrical but is not full visible. Primary venation is pinnate. Secondary venation is craspedodromous. Intersecondary veins are absent. Intercostal tertiary veins are opposite percurrent. Teeth are regularly spaced, shallowly serrate to crenate, and glandular.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0118

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	Base Angle	obtuse
Laminar Shape	elliptic	Apex Angle	obtuse
Laminar Symmetry	asymmetrical	Base Shape	not visible
L:W Ratio	1:1	Apex Shape	not visible
Base Symmetry	not visible	Margin Type	serrate; crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior Secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	5?	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	convex; straight	Epimedial3° proximal course	parallel to intercostal tertiaries
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing exmedially	4° Vein Category	opposite percurrent
Exterior tertiary course	looped	5° Vein Category	irregular reticulate

FINER VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	5	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cv/fl; st/fl; cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Incertae sedis		Morphotype #	FL010
Major Plant Group: DIC	Organ Type: Leaf	Plant Family	Genus	Type spec. #	RYS06-0183

PHOTO

Description of morphotype:

Obovate microphyll leaf with leaf teeth in upper half of leaf only. Teeth are crenate to serrate. Base angle is acute and cuneate in shape. Apex angle is obtuse and rounded in shape, terminal apex slightly retuse. Pinnate primary venation and craspedodromous secondaries. Higher level venation indistinct. Possibly Fagaceae sp.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0183

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	Base Angle	acute
Laminar Shape	obovate	Apex Angle	obtuse
Laminar Symmetry	symmetrical	Base Shape	cuneate
L:W Ratio	1.9:1	Apex Shape	rounded; retuse
Base Symmetry	symmetrical	Margin Type	serrate; crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	not visible
2° Vein Category	craspedodromous	Length	not visible
2° Vein Spacing	not visible	Proximal course	not visible
2° Vein Angle	not visible	Distal course	not visible
2° attachment	excurrent	Vein frequency	not visible

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course	not visible	Epimedial3° proximal course	not visible
3° Angle to 1°	not visible	Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINER VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	yes / no
Teeth/cm	4	Teeth round	yes / no
Spacing	regular	Teeth acute	yes / no
Shape	cv/cv; st/cv; st/fl	Principal vein	not visible
Sinus	angular	Termination	not visible
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Juglandaceae sp.	Morphotype #	FL011

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Juglandaceae	Genus		Type spec. #	RYS06-0893

PHOTO

Description of morphotype:

Oblong to elliptic leaflet, microphyll to mesophyll in size but predominantly notophyll. Lamina is generally symmetrical and base is asymmetrical (basal insertion point asymmetrical) to occasionally symmetrical, suggesting that this is a leaflet of a compound leaf. Secondary veins are irregularly spaced and close together; in some specimens they are wavy and dip together. At least 12 pairs of secondaries, opposite one another off midrib with some offsets. Evidence of insect predation on the morphotype is common (bites and egg laying). Primary venation is pinnate. Secondary venation is craspedodromous and intersecondaries are present. Teeth are large and irregular to occasionally regular.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes (RP=Republic, MB=McAbee)	RP059? MB046?

Falkland Specimens:

RYS06-0040, RYS06-0095, RYS06-0148, RYS06-0155, RYS06-0167, RYS06-0228, RYS06-0229, RYS06-0270, RYS06-0285, RYS06-0308, RYS06-0312, RYS06-0315, RYS06-0417, RYS06-0727, RYS06-0761, RYS06-0769, RYS06-0787, RYS06-0792, RYS06-0815, RYS06-0861, RYS06-0862, RYS06-0893, RYS06-0919, RYS06-0939, RYS06-0964, RYS06-1005, RYS07-0132, RYS07-0152, RYS07-0153, RYS07-0304, RYS07-0333, RYS07-0510, RYS07-0521, RYS07-0595, RYS07-0645, RYS07-0706, RYS07-0879, RYS07-0968, RYS08-0018, RYS08-0052

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	mesophyll 2	Base Angle	obtuse
			Apex Angle	acute
Laminar Shape	oblong	elliptic	Base Shape	convex; cuneate
Laminar Symmetry	symmetrical	L:W Ratio 2.3:1	Apex Shape	convex; straight
Base Symmetry	asymmetrical		Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	inconsistent	Distal course	not visible
2° attachment	decurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	ramified
3° Vein Course	exmedially ramified	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	not visible	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	poorly developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2-3	Teeth Round	○ yes ◉ no
Spacing	irregular	Teeth Acute	◉ yes ○ no
Shape	fl/fl; st/fl; cv/cv; cc/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Metasequoia occidentalis	Morphotype #	FL012

Major Plant Group	CON	Organ Type	Leaf	Plant Family	Cupressaceae	Genus	*Metasequoia*	Type spec. #	RYS07-0197

PHOTO

Description of morphotype:

Typically preserved as detached branchlets. Needles linear to slightly ovate, 1-2 mm in width, variable in length but up to 15 mm long in some of the larger specimens. Needles are decussate to sub-opposite and petiolate with slender axis. Angle of needle attachment variable but typically 40-60˚. Midvein of needle is prominent, and tips of needles convex to acuminate in shape, bluntly pointed.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP116
MB009

Falkland Specimens:

Found in almost all quarries, 348 specimens. Most abundant in Units 1 & 2.

Leaf Architecture - Dicots Only

LEAF				
Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS		TEETH			
Areolation		# of Orders		Teeth Close	◌ yes ◌ no
F.E.V.s		Teeth/cm		Teeth round	◌ yes ◌ no
Marginal Ultimate Venation		Spacing		Teeth acute	◌ yes ◌ no
		Shape		Principal vein	
		Sinus		Termination	
		Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	cf. Malus idahoensis		Morphotype #	FL013
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Rosaceae
Genus	*c.f. Malus*	Type spec. #	RYS08-0016		

PHOTO

Description of morphotype:

Laminar size microphyll to mesophyll, but predominantly mesophyll. Secondary veins depart at approximately 65 degree angle from midrib, becoming more acute at the apex. 11+ pairs leaving the midrib opposite one another. Tertiary veins appear perpendicular to obtuse to the midrib and generally are uniform angle across the leaf surface (becoming slightly more acute exmedially). No teeth in the bottom quarter of the leaf. Teeth are large, rather widely spaced at base, closer together near the apex. Strong intersecondaries are present.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0078, RYS06-0100, RYS06-0102, RYS06-0157, RYS06-0261, RYS06-0277, RYS06-0288, RYS06-0321, RYS06-0386, RYS06-0398, RYS06-0706, RYS06-0755, RYS06-0802, RYS06-0844, RYS06-0847, RYS06-0921, RYS06-0956, RYS07-0112, RYS07-0125, RYS07-0143, RYS07-0150, RYS07-0188, RYS07-0238, RYS07-0290, RYS07-0647, RYS07-0835, RYS07-0869, RYS07-0886, RYS07-0917, RYS08-0007, RYS08-0016

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	mesophyll 3	Base Angle	obtuse
Laminar Shape	elliptic		Apex Angle	obtuse
Laminar Symmetry	symmetrical	L:W Ratio 1.2-1.5:1	Base Shape	convex
Base Symmetry	basal insertion asymmetrical		Apex Shape	convex / rounded
			Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	parallel to major secondaries
2° Vein Angle	smoothly increasing towards base	Distal course	reticulating or ramifying
2° attachment	decurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial3°	ramified
3° Vein Course	straight / convex	Epimedial3° proximal course	not applicable
3° Angle to 1°	perpendicular	Epimedial3° distal course	not applicable
3° Vein Angle Variability	uniform to decreasing slightly exmedially	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth Round	○ yes ◉ no
Spacing	irregular	Teeth Acute	◉ yes ○ no
Shape	cv/cv st/fl st/st fl/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple or non-specific	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Incertae sedis	Morphotype #	FL014
Major Plant Group	DIC	Organ Type	Leaf
Plant Family		Genus	
Type spec. #	RYS06-0786		

PHOTO

Description of morphotype:

Microphyll to notophyll elliptic leaf with serrate margin. Apex is missing in type specimen, but in other specimens is acuminate. Base is obtuse and rounded to convex in shape. Primary venation pinnate with no agrophic veins. Secondary venation semicraspedodromous. Secondary veins are uniform in angle and spacing across the leaf surface, 7-10 pairs of secondaries depart the midrib approximately opposite, and are wavy in appearance (deflected at points of tertiary attachment). Intercostal tertiaries are opposite percurrent, convex to sinuous course. Teeth are simple, regular and serrate.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP159?

Falkland Specimens:

RYS06-0034, RYS06-0223, RYS06-0324, RYS06-0339, RYS06-0786, RYS06-0854, RYS06-0913, RYS06-0936, RYS06-0937, RYS07-0119, RYS07-0291, RYS07-0587, RYS07-0642

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	
Clamp Size	microphyll 3	mesophyll 1	
Laminar Shape	elliptic		
Laminar Symmetry	symmetrical	L:W Ratio	1.3-1.6:1
Base Symmetry	symmetrical		
Petiolar Attach.	marginal		
Base Angle	obtuse	Apex Angle	acute
Base Shape	rounded	convex	
Apex Shape	acuminate		
Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate
Agrophic Veins	none
# of Basal Veins	1
2° Vein Category	semicraspedodromous
2° Vein Spacing	uniform
2° Vein Angle	uniform
2° attachment	decurrent
Interior secondaries	absent
Minor 2° course	not applicable
Inter-2° Veins	absent
Length	not applicable
Proximal course	not applicable
Distal course	not applicable
Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	
3° Vein Course	convex	sinuous
3° Angle to 1°	obtuse	
3° Vein Angle Variability	decreasing exmedially	
Exterior tertiary course	looped	
Epimedial3°	opposite percurrent	
Epimedial3° proximal course	parallel to intercostal tertiaries	
Epimedial3° distal course	parallel to intercostal tertiaries	
4° Vein Category	irregular reticulate	
5° Vein Category	dichotomizing (fevs)	

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders	1		
Teeth/cm	2		
Spacing	regular		
Shape	fl/fl	cc/fl	cc/cv
Sinus	angular		
Apex	simple		
Teeth Close	○ yes	◉ no	
Teeth Round	○ yes	◉ no	
Teeth Acute	◉ yes	○ no	
Principal vein	present		
Termination	at apex of tooth		
Accesory vein	straight or concave		

Falkland (BC) Flora	Morphotype Name	?Lauraceae sp.	Morphotype #	FL015

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	?Lauraceae	Genus		Type spec. #	RYS06-0293

PHOTO

Description of morphotype:

Leaf is smoothly elliptical, microphyll to mesophyll in size. Margin is entire with erose edges (minutely irregular). Apex is not preserved. Secondaries are brochidodromous and irregularly spaced. There is one pair of acute basal secondary veins. Intersecondary veins are present.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes RP=Republic MB=McAbee	MB057?

Falkland Specimens:

RYS06-0293
RYS07-0335
RYS08-0045

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll	Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 1	Base Angle	acute	Apex Angle	not visible
Laminar Shape	elliptic		Base Shape	cuneate	concave	
Laminar Symmetry	symmetrical	L:W Ratio 2:1	Apex Shape	not visible		
Base Symmetry	basal symmetrical to width asymmetrical		Margin Type	entire	erose	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	brochidodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	one pair acute basal secondaries	Distal course	basiflexed
2° attachment	decurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial3°	mixed
3° Vein Course		Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	basiflexed
3° Vein Angle Variability	inconsistent	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL016

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf			RYS06-0859

PHOTO

Description of morphotype:

Notophyll leaf, smoothly elliptical to slightly obovate. Base and apex angles acute. Margin appears entire but on closer examination has very small glandular teeth (more pronounced near apex of leaf). Primary venation is pinnate. Secondary venation is craspedodromous, with veins terminating at the margin, sometimes at a sinus. Secondaries are uniform in spacing and angle of attachment. Intercostal tertiaries are opposite percurrent. Teeth are small, irregular, and simple.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0859

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	Petiolar Attach.	marginal
Clamp Size	mesophyll 1	Base Angle	acute
Laminar Shape	obovate	Apex Angle	acute
Laminar Symmetry	symmetrical	Base Shape	cuneate; convex
L:W Ratio	2.4:1	Apex Shape	convex
Base Symmetry	symmetrical	Margin Type	serrate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	sinuous; convex	Epimedial3° proximal course	parallel to intercostal tertiaries
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	alternate percurrent
Exterior tertiary course	terminating at margin	5° Vein Category	regular reticulate

FINE VEINS

Areolation	well developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cv/cv cv/fl	Principal vein	absent
Sinus	angular	Termination	not applicable
Apex	simple	Accesory vein	not applicable

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL018

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS08-0013

PHOTO

Description of morphotype:

Pinnately veined microphyll leaf with semi-craspedodromous secondary veins. Secondaries depart the midrib opposite near the base, becoming alternate closer to apex. Angle of departure and spacing relatively uniform (slightly closer together and more acute at apex). Teeth are fl/fl and glandular, regularly spaced. FEVs appear to be primarily one-branched.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0908
RYS08-0013

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal
Clamp Size	microphyll 2		Base Angle	obtuse
Laminar Shape	ovate	elliptic	Apex Angle	obtuse
Laminar Symmetry	symmetrical	L:W Ratio 1.3-1.6:1	Base Shape	convex
Base Symmetry	symmetrical		Apex Shape	convex
			Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	alternate percurrent	Epimedial3°	mixed
3° Vein Course		Epimedial3° proximal course	not applicable
3° Angle to 1°	obtuse	Epimedial3° distal course	not applicable
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	1-branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders	1	Teeth Close	◯ yes ◉ no
Teeth/cm	2	Teeth round	◯ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ◯ no
Shape	fl/fl cc/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Pinus sp. seed	Morphotype #	FL019

Major Plant Group	CON	Organ Type	Seeds	Plant Family	Pinaceae	Genus	*Pinus*	Type spec. #	RYS06-0940

PHOTO

Description of morphotype:

Holomorphotype is relatively large, the wing about 2 cm long to the point of seed attachment. The wing is 1 cm broad at widest point. The top of the wing is quite straight, the distal point acute, then forming a straight line to the widest point of wing, and straight across to the base of seed attachment (actual seed is often missing).

Distribution at Falkland site

Unit	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP146
MB205

Falkland Specimens:

RYS06-0115
RYS06-0217
RYS06-0514
RYS06-0940
RYS07-0844
RYS07-0845

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Alnus sp. 1	Morphotype #	FL020
Major Plant Group	DIC	Organ Type	Leaf
Plant Family	Betulaceae	Genus	*Alnus*
Type spec. #	RYS06-0375		

PHOTO

Description of morphotype:

Microphyll to notophyll elliptic or ovate leaf. Lamina and base are symmetrical. Apex is acute and straight or convex, base is narrowly obtuse and convex or concavo-convex. Primary venation is pinnate and major secondaries are craspedodromous; agrophic veins and intersecondaries absent. Secondaries depart the midvein opposite in bottom half of leaf, becoming alternate near the apex, with about 10 pair of secondaries. Teeth are sharply and shallowly serrate with 2 orders of teeth present, 2 subsidiary teeth typically on basal side of primary teeth. Tooth apices simple or glandular. This may be a more mature leaf of Alnus parvifolia (compare with FL023). Compare with FL117 and FL159.

Distribution at Falkland site

Unit 3 ☒
Unit 2 ☒
Unit 1 ☒
Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

71 specimens in three units and scree.

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll		
Clamp Size	microphyll 2	microphyll 1		
Laminar Shape	elliptic	ovate		
Laminar Symmetry	symmetrical	L:W Ratio	1.8-1.9:1	
Base Symmetry	symmetrical			
Petiolar Attach.	marginal			
Base Angle	obtuse	Apex Angle	acute	
Base Shape	concavo-convex	convex		
Apex Shape	convex	straight		
Margin Type	serrate	Lobation	unlobed	

1° to 2°

1° Vein Category	pinnate
Agrophic Veins	none
# of Basal Veins	1
2° Vein Category	craspedodromous
2° Vein Spacing	uniform
2° Vein Angle	uniform
2° attachment	excurrent
Interior secondaries	absent
Minor 2° course	not applicable
Inter-2° Veins	absent
Length	not applicable
Proximal course	not applicable
Distal course	not applicable
Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	
3° Vein Course	convex	sinuous
3° Angle to 1°	obtuse	
3° Vein Angle Variability	increasing basally	
Exterior tertiary course	terminating at margin	
Epimedial3°	opposite percurrent	
Epimedial3° proximal course	perpendicular to midvein	
Epimedial3° distal course	parallel to intercostal tertiaries	
4° Vein Category	alternate percurrent	
5° Vein Category	irregular reticulate	

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	2		
Teeth/cm	3		
Spacing	regular		
Shape	st/cv	st/fl	cv/cv
Sinus	angular		
Apex	simple or glandular		
Teeth Close	○ yes	◉ no	
Teeth Round	○ yes	◉ no	
Teeth Acute	◉ yes	○ no	
Principal vein	present		
Termination	at apex of tooth		
Accesory vein	not visible		

Falkland (BC) Flora	Morphotype Name	Ulmus okanaganensis type 2	Morphotype #	FL021

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Ulmaceae	Genus	*Ulmus*	Type spec. #	RYS06-0970

PHOTO

Description of morphotype:

Ovate to elliptic leaf with cordate base and acuminate apex. Basal extension is slightly asymmetrical. Laminar size nanophyll to notophyll, but predominantly microphyll. Primary venation is pinnate. Secondary venation craspedodromous, veins regularly spaced, straight, and close together (3-4 mm apart), about 13 pairs of secondaries departing from the midrib mostly opposite except at apex. Teeth regular and compound, with smaller secondary tooth on the basal side of the primary tooth. This is leaf type 2 of Denk and Dillhoff (2005), interpreted as elongation-shoot leaves. See FL081 for type 1. FL021 and FL081 treated as single morphotype in all analyses of diversity and climate.

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee
	Unit 3 ☒	RP050
	Unit 2 ☒	MB038
	Unit 1 ☒	MB042
	Scree ☐	

Falkland Specimens:

RYS06-0131, RYS06-0189, RYS06-0206, RYS06-0237, RYS06-0681, RYS06-0954, RYS06-0970, RYS06-0978, RYS06-0988, RYS07-0014, RYS07-0034, RYS07-0141, RYS07-0177, RYS07-0245, RYS07-0325, RYS07-0327, RYS07-0342, RYS07-0467, RYS07-0594, RYS07-0625, RYS07-0634, RYS07-0648

Leaf Architecture - Dicots Only

LEAF

Laminar Size	nanophyll	notophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 1	mesophyll 1	Base Angle	obtuse
			Apex Angle	acute
Laminar Shape	ovate	elliptic	Base Shape	cordate, convex
Laminar Symmetry	symmetrical	L:W Ratio 1.8-2.0:1	Apex Shape	acuminate
Base Symmetry	basal extension asymmetrical		Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	mixed opp/alt	alternate percurrent	Epimedial3°	not visible
3° Vein Course			Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse		Epimedial3° distal course	not visible
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	mixed percurrent
Exterior tertiary course	terminating at margin		5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	◉ yes ○ no
Teeth/cm	2-4	Teeth round	○ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	fl/fl, cv/cv, fl/cv, cc/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Ternstroemites sp. "B"	Morphotype #	FL022

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Theaceae	Genus	*Ternstroemites*	Type spec. #	RYS06-0036

PHOTO

Description of morphotype:

Obovate to elliptic notophyll leaf with crenate margin, teeth possibly setaceous in upper part of the leaf. Secondary veins semicraspedodromous. Two pairs of acute basal secondary veins appear somewhat wavy (other secondaries straight) and parallel the margin, the inner pair very close to the margin. Higher order venation indistinct. Midrib very stout. Petiole stout and curved. Tooth spacing regular, with simple teeth about 2/cm. Tooth shapes cv/cv and cc/cv. Tooth apex simple or setaceous. Leaf texture is thin with a smooth, almost shiny appearance in type specimen.

Distribution at Falkland site		Similar Morphotypes	
	Unit 3 ☒	RP=Republic	
	Unit 2 ☒	MB=McAbee	
	Unit 1 ☐		
	Scree ☐		

Falkland Specimens:

RYS06-0036, RYS06-0691, RYS06-0765, RYS06-0780, RYS06-0842, RYS06-0914, RYS06-0980, RYS07-0129, RYS07-0364, RYS07-0504

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 1	Base Angle	acute	Apex Angle	obtuse
Laminar Shape	elliptic	obovate	Base Shape	convex	concave	
Laminar Symmetry	symmetrical	L:W Ratio 1.8:1	Apex Shape	convex		
Base Symmetry	symmetrical		Margin Type	crenate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	not visible
3° Vein Course			Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse		Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible		4° Vein Category	not visible
Exterior tertiary course	looped		5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders	1		Teeth Close	◌ yes ◉ no
Teeth/cm	2		Teeth Round	◉ yes ◌ no
Spacing	regular		Teeth Acute	◌ yes ◉ no
Shape	cv/cv	cc/cv	Principal vein	not visible
Sinus	angular		Termination	not visible
Apex	setaceous		Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Alnus parvifolia	Morphotype #	FL023

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Betulaceae	Genus	*Alnus*	Type spec. #	RYS07-0791

PHOTO

Description of morphotype:

Leaf shape may be variable, from elliptic to ovate, and size is almost exclusively microphyll. Primary venation is pinnate. Secondary veins are craspedodromous, parallel and relatively straight to slightly curved, departing the midrib from an angle of 40-45 degrees, simple or occasionally with branches. Tertiary veins are opposite percurrent, and the most exmedial tertiary vein forms a chevron sending a branch straight to a tooth. Teeth are small and serrate, closely spaced (7-9 per cm) with glandular apices, appearing "knobby" in some specimens. Teeth appear to be only of one order, distinguishing this morphotype from FL020 (but could be difference between young and mature leaves).

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes RP=Republic MB=McAbee	RP020 MB043

Falkland Specimens:

107 specimens in three units and scree.

Leaf Architecture - Dicots Only

LEAF

Laminar Size	nanophyll	microphyll	
Clamp Size	microphyll 1	microphyll 3	
Laminar Shape	elliptic	ovate	
Laminar Symmetry	symmetrical	L:W Ratio	1.5-2.2:1
Base Symmetry	symmetrical		

Petiolar Attach.	marginal		
Base Angle	obtuse	Apex Angle	acute
Base Shape	convex		
Apex Shape	convex		
Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate
Agrophic Veins	none
# of Basal Veins	1
2° Vein Category	craspedodromous
2° Vein Spacing	uniform
2° Vein Angle	smoothly increasing towards base
2° attachment	excurrent

Interior secondaries	absent
Minor 2° course	not applicable
Inter-2° Veins	absent
Length	not applicable
Proximal course	not applicable
Distal course	not applicable
Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	
3° Vein Course	straight	convex
3° Angle to 1°	obtuse	
3° Vein Angle Variability	increasing basally	
Exterior tertiary course	terminating at margin	

Epimedial3°	opposite percurrent
Epimedial3° proximal course	parallel to intercostal tertiaries
Epimedial3° distal course	parallel to intercostal tertiaries
4° Vein Category	not visible
5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1		
Teeth/cm	7-9		
Spacing	regular		
Shape	st/st	cv/cv	fl/cv
Sinus	angular		
Apex	non-specific glandular		

Teeth Close	◉ yes ○ no
Teeth round	○ yes ◉ no
Teeth acute	◉ yes ○ no
Principal vein	present
Termination	at apex of tooth
Accesory vein	convex

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL024

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0650

PHOTO

Description of morphotype:

Microphyll to mesophyll narrow ovate leaf with entire margin. Apex is acute and acuminate; base is obtuse and convex. Primary venation is pinnate. Secondary venation brochidodromous. Intersecondary veins present. Intercostal tertiaries opposite percurrent to irregular reticulate. Higher order venation indistinct.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0038
RYS06-0650
RYS07-0741
RYS07-0864

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll		Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 2		Base Angle	obtuse	Apex Angle	acute
Laminar Shape	ovate			Base Shape	convex		
Laminar Symmetry	symmetrical	L:W Ratio	2.2-2.8:1	Apex Shape	acuminate		
Base Symmetry	not visible			Margin Type	entire	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	strong
2° Vein Category	brochidodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	inconsistent	Distal course	parallel to major secondary
2° attachment	decurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	irregular reticulate	Epimedial3°	opposite percurrent
3° Vein Course			Epimedial3° proximal course	parallel to intersecondary
3° Angle to 1°	obtuse		Epimedial3° distal course	basiflexed
3° Vein Angle Variability	inconsistent		4° Vein Category	not visible
Exterior tertiary course	looped		5° Vein Category	not visible

FINER VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL025

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0649

PHOTO

Description of morphotype:

Notophyll obovate leaf with entire margin. Apex is rounded to slightly retuse. Base is not visible. Lamina appears curved. Primary venation is pinnate. Secondary venation is brochidodromous. Intercostal tertiaries are opposite percurrent. Higher order venation indistinct.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0649

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	not visible	
Clamp Size	mesophyll 1		Base Angle	not visible	Apex Angle: obtuse
Laminar Shape	obovate		Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio: 1.5:1	Apex Shape	rounded	retuse
Base Symmetry	not visible		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	absent
2° Vein Category	brochidodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	convex	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	not visible
Exterior tertiary course	looped	5° Vein Category	not visible

FV INEINERS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	?Corylus sp.	Morphotype #	FL026

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Betulaceae	Genus	*?Corylus*	Type spec. #	RYS06-0168

PHOTO

Description of morphotype:

Only the base of the type specimen is present; it shows a strongly cordate base with lobes almost meeting at the base. Leaf is microphyll to notophyll and elliptic to ovate in shape. Primary venation is pinnate with compound agrophic veins. Major secondaries are craspedodromous. At the base of the leaf, the tertiary veins form almost a complete circle (basally concentric). The teeth are compound, regularly spaced, and simple or glandular. The tooth sinuses are angular, and a number of small exterior tertiary veins (and accessory veins) meet at the sinuses. Compare for possible reassignment to Tsukada davidiifolia (Wolfe and Wehr, 1987).

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☒
Scree	☐

Similar Morphotypes RP=Republic MB=McAbee	RP327

Falkland Specimens:

RYS06-0011
RYS06-0168
RYS07-0713

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal	
Clamp Size	microphyll 3	mesophyll 1	Base Angle	wide obtuse	Apex Angle: not visible
Laminar Shape	elliptic	ovate	Base Shape	cordate	
Laminar Symmetry	symmetrical	L:W Ratio ~1.3:1	Apex Shape	not visible	
Base Symmetry	symmetrical		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	compound	Minor 2° course	craspedodromous
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	opposite percurrent
3° Vein Course	convex	sinuous	Epimedial3° proximal course	obtuse to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing exmedially (basally concentric)		4° Vein Category	alternate percurrent
Exterior tertiary course	terminating at margin		5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders	2	Teeth Close	◉ yes ○ no
Teeth/cm	4	Teeth Round	○ yes ◉ no
Spacing	regular	Teeth Acute	◉ yes ○ no
Shape	fl/fl cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	running from sinus

Falkland (BC) Flora	Morphotype Name	?Salicaceae sp. 1	Morphotype #	FL028
Major Plant Group: DIC	Organ Type: Leaf	Plant Family: Salicaceae	Genus:	Type spec. #: RYS06-0152

PHOTO

Description of morphotype:

Leaf is very incomplete, but appears to be oblong (or possibly elliptical) with fine, glandular (spherulate), serrulate teeth. Teeth are regular to irregular, very close together, and occasionally compound. Primary venation is pinnate, with semi-craspedodromous secondaries curving up towards the margin.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0152

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	not visible
Clamp Size	mesophyll 1		Base Angle	not visible; Apex Angle: not visible
Laminar Shape	elliptic		Base Shape	not visible
Laminar Symmetry	symmetrical	L:W Ratio:	Apex Shape	not visible
Base Symmetry	not visible		Margin Type	serrate; Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	not visible	Minor 2° course	craspedodromous
# of Basal Veins	not visible	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	not visible
3° Vein Course	sinuous; convex	Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse	Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible	4° Vein Category	irregular reticulate
Exterior tertiary course	terminating at margin	5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	10	Teeth Round	○ yes ◉ no
Spacing	regular	Teeth Acute	◉ yes ○ no
Shape	cv/cv st/st st/cv fl/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	spherulate	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL029

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0091

PHOTO

Description of morphotype:

Notophyll elliptic leaf with asymmetrical (to occasionally symmetrical) base and irregularly serrate to crenate margin. Primary venation is pinnate with no agrophic veins. Secondary veins are craspedodromous. Secondaries often have exmedial branches. Lowermost secondaries running quite close and parallel to the margin, ending in the lowermost teeth. Intersecondaries weakly present. Intercostal tertiaries are generally opposite to alternate percurrent. Teeth are irregular and shallowly serrate to crenate with glandular apices. Possibly Alnus sp.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

MB074?

Falkland Specimens:

RYS06-0088, RYS06-0091, RYS06-0272, RYS06-0287, RYS06-0323, RYS06-0845, RYS06-0981, RYS07-0021, RYS07-0298, RYS07-0867

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	marginal
Clamp Size	microphyll 3	mesophyll 1	Base Angle	obtuse; Apex Angle: obtuse
Laminar Shape	elliptic	ovate	Base Shape	concavo-convex; convex
Laminar Symmetry	symmetrical	L:W Ratio 1.6:1	Apex Shape	convex; acuminate
Base Symmetry	asymmetrical		Margin Type	serrate; crenate; Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	decreasing toward base	Proximal course	perpendicular to midvein
2° Vein Angle	uniform	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial 3°	opposite percurrent
3° Vein Course	sinuous	Epimedial 3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial 3° distal course	basiflexed
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	alternate percurrent
Exterior tertiary course	looped	5° Vein Category	regular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	1-branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth Round	◉ yes ○ no
Spacing	irregular	Teeth Acute	◉ yes ○ no
Shape	cv/cv st/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL030

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0746

PHOTO

Description of morphotype:

Microphyll to notophyll elliptic leaf with very small glandular teeth appearing as bumps on the margin. Apex and base angles acute. Primary venation pinnate. Secondary venation craspedodromous with no intersecondaries. Secondary veins curve smoothly upwards. Secondaries depart the midvein at a slight offset. Tertiaries are opposite percurrent and mostly straight and simple. Tertiary vein closest to the margin is convex and has a perpendicular branch midway across that either runs directly to the margin or forks before meeting the margin.

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee	
	Unit 3 ☒		RP221?
	Unit 2 ☒		
	Unit 1 ☒		
	Scree ☒		

Falkland Specimens:

RYS06-0124, RYS06-0746, RYS07-0003, RYS07-0044, RYS07-0328, RYS07-0394, RYS07-0414, RYS08-0054

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal	
Clamp Size	microphyll 2	mesophyll 1	Base Angle	acute	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	concave	
Laminar Symmetry	symmetrical	L:W Ratio: 1.5-1.9:1	Apex Shape	convex	straight
Base Symmetry	not visible		Margin Type	serrate	dentate; Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	opposite percurrent
3° Vein Course	sinuous	convex	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	alternate percurrent
Exterior tertiary course	terminating at margin		5° Vein Category	dichotomizing (fevs)

FINER VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1		Teeth Close	○ yes ⊗ no
Teeth/cm	3		Teeth round	⊗ yes ○ no
Spacing	regular		Teeth acute	⊗ yes ○ no
Shape	cv/fl	st/fl	Principal vein	not visible
Sinus	angular		Termination	not visible
Apex	non-specific glandular		Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Cupressaceae cf. Thuja	Morphotype #	FL031

Major Plant Group	CON	Organ Type	Leaf	Plant Family	Cupressaceae	Genus	*cf. Thuja*	Type spec. #	RYS08-0059

PHOTO

Description of morphotype:

Pairs of closely appressed scale-like leaves, decussately arranged. Branchlets are alternately arranged, rather than opposite as in Cupressinocladus, forming flattened sprays.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP113
RP137
MB012
MB011

Falkland Specimens:

RYS06-0044, RYS06-0051, RYS06-0120, RYS06-0162, RYS06-0244, RYS06-0345, RYS06-0350, RYS06-0351, RYS06-0354, RYS06-0372, RYS06-0384, RYS06-0510, RYS06-0530, RYS06-0611, RYS06-0627, RYS06-0920, RYS06-1009, RYS06-1016, RYS06-1043, RYS07-0094, RYS07-0102, RYS07-0138, RYS07-0145, RYS07-0162, RYS07-0181, RYS07-0190, RYS07-0230, RYS07-0252, RYS07-0381, RYS07-0389, RYS07-0423, RYS07-0496, RYS07-0569, RYS07-0659, RYS07-0743, RYS07-0786, RYS07-0822, RYS08-0034, RYS08-0059

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Ulmus sp.	Morphotype #	FL032

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Fruit	Ulmaceae	*Ulmus*	RYS06-0054

PHOTO

Description of morphotype:

Fruit is a samara, wingless or wings inconspicuous, endocarp oval to elliptical, ~3-4 mm long and 2-3 mm wide, with two persistent styles 1.5-2.0 mm long. Some specimens have perianth remnants at base (e.g. holomorphotype specimen RYS06-0054). Specimen RYS08-0062 is a rare example of a specimen with peripheral hairs preserved.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☒
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP066
RP310
MB313

Falkland Specimens:

RYS06-0054, RYS06-0159, RYS06-0216, RYS06-0242, RYS06-0325, RYS06-0365, RYS06-0366, RYS06-0367, RYS06-0388, RYS06-0578, RYS06-0648, RYS06-0885, RYS06-0912, RYS06-1026, RYS06-1051, RYS07-0092, RYS07-0211, RYS07-0280, RYS07-0311, RYS07-0787, RYS07-0795, RYS07-0813, RYS07-0825, RYS07-0826, RYS07-0831, RYS07-0898, RYS07-0901, RYS07-0942, RYS08-0039, RYS08-0062

Leaf Architecture - Dicots Only

LEAF

Laminar Size / Clamp Size / Laminar Shape / Laminar Symmetry / L:W Ratio / Base Symmetry / Petiolar Attach. / Base Angle / Apex Angle / Base Shape / Apex Shape / Margin Type / Lobation

1° to 2°

1° Vein Category / Agrophic Veins / # of Basal Veins / 2° Vein Category / 2° Vein Spacing / 2° Vein Angle / 2° attachment / Interior secondaries / Minor 2° course / Inter-2° Veins / Length / Proximal course / Distal course / Vein frequency

3° to 5°

3° Vein Category / 3° Vein Course / 3° Angle to 1° / 3° Vein Angle Variability / Exterior tertiary course / Epimedial3° / Epimedial3° proximal course / Epimedial3° distal course / 4° Vein Category / 5° Vein Category

FINE VEINS

Areolation / F.E.V.s / Marginal Ultimate Venation

TEETH

# of Orders / Teeth/cm / Spacing / Shape / Sinus / Apex / Teeth Close ◌ yes ◌ no / Teeth round ◌ yes ◌ no / Teeth acute ◌ yes ◌ no / Principal vein / Termination / Accesory vein

Falkland (BC) Flora	Morphotype Name	Pinus sp.	Morphotype #	FL033

Major Plant Group	CON	Organ Type	Leaf	Plant Family	Pinaceae	Genus	*Pinus*	Type spec. #	RYS07-0913

PHOTO

Description of morphotype:

Needles in bundles of 5 (some specimens with fewer; may be another species, or may be incomplete). Needles variable in length, from ~4 cm to 7.5+ cm long and each needle approximately 1 mm wide.

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee
	Unit 3 ☒	RP065
	Unit 2 ☒	RP123
	Unit 1 ☒	RP234
	Scree ☒	MB003

Falkland Specimens:

RYS06-0046, RYS06-0181, RYS06-0340, RYS06-0454, RYS06-0586, RYS06-0603, RYS06-0910, RYS06-0926, RYS06-0950, RYS06-0997, RYS06-1001, RYS06-1035, RYS07-0070, RYS07-0222, RYS07-0289, RYS07-0301, RYS07-0324, RYS07-0422, RYS07-0537, RYS07-0564, RYS07-0605, RYS07-0670, RYS07-0704, RYS07-0775, RYS07-0830, RYS07-0843, RYS07-0913, RYS07-0967

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Betula leopoldae	Morphotype #	FL034

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Betulaceae	Genus	*Betula*	Type spec. #	RYS07-0195

PHOTO

Description of morphotype:

Notophyll leaf with cordate base and serrate compound teeth. Leaf shape is ovate to elliptic and symmetrical to slightly asymmetrical at the base. Primary venation is pinnate and major secondaries are craspedodromous. Secondaries depart the midvein at ~40˚, fairly straight to slightly convex. Tertiary venation is opposite percurrent. Higher order venation indistinct. Teeth are sharply serrate, closely spaced, and compound.

Distribution at Falkland site

Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP022
MB025

Falkland Specimens:

RYS06-0132, RYS06-0378, RYS06-0800, RYS06-0810, RYS06-0933, RYS07-0041, RYS07-0076, RYS07-0195, RYS07-0319, RYS07-0345, RYS07-0374

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	Petiolar Attach.	marginal
Clamp Size	mesophyll 1	Base Angle	obtuse
Laminar Shape	ovate / elliptic	Apex Angle	acute
Laminar Symmetry	symmetrical	Base Shape	cordate
L:W Ratio	1.7:1	Apex Shape	straight / convex
Base Symmetry	symmetrical or slightly asymmetrical	Margin Type	serrate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	convex / straight	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing basally	4° Vein Category	not visible
Exterior tertiary course	terminating at margin	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	◉ yes ○ no
Teeth/cm	5-6	Teeth round	○ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cv/cv fl/fl st/fl cc/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL035

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0302

PHOTO

Description of morphotype:

Microphyll elliptic leaf with entire margin. Apex is convex to slightly retuse. Primary venation is pinnate with no agrophic veins. Major secondaries are festooned brochidodromous, with the inner (primary) set of arches set quite far back from margin. Intersecondary veins are present. Tertiary venation is irregular reticulate.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP228?
MB061?

Falkland Specimens:

RYS06-0302

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 2		Base Angle	obtuse	Apex Angle: obtuse
Laminar Shape	elliptic		Base Shape	convex	
Laminar Symmetry	symmetrical	L:W Ratio: 1.8:1	Apex Shape	convex	retuse
Base Symmetry	symmetrical		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	festooned brochidodromous	Length	>50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	perpendicular to midvein
2° Vein Angle	smoothly decreasing towards base	Distal course	parallel to major secondary
2° attachment	excurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	reticulate
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL036

Major Plant Group	CON	Organ Type	Reproductive	Plant Family		Genus		Type spec. #	RYS06-0849

PHOTO

Description of morphotype:

Two pollen cones, associated but attachment not visible. Cones >20 mm long, ~5 mm wide. Cones are highly carbonized. Similar cones from the McAbee site are tentatively identified as Cunninghamia sp. (MB215).

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes
RP=Republic
MB=McAbee

MB215?

Falkland Specimens:

RYS06-0849

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	yes no
Teeth/cm		Teeth round	yes no
Spacing		Teeth acute	yes no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Sequoia affinis	Morphotype #	FL037

Major Plant Group	CON	Organ Type	Leaf	Plant Family	Cupressaceae	Genus	*Sequoia*	Type spec. #	RYS06-0123

PHOTO

Description of morphotype:

Typically preserved as detached branchlets. Needles variable, some appearing scale-like and spirally arranged (short shoots), and others with broader needles (long shoots), spiral to sub-opposite in arrangement and sessile.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP064
MB010

Falkland Specimens:

93 specimens in three units.

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

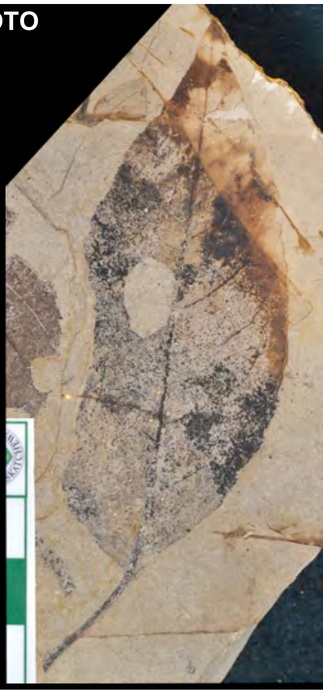
Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis		Morphotype #	FL039
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	
Genus		Type spec. #	RYS06-0935		

PHOTO



Description of morphotype:

Microphyll to notophyll leaf with acuminate tip and shallow, irregular teeth. Petiole is long and curved. Base is typically symmetrical to occasionally asymmetrical, convex to straight in shape. Primary venation is pinnate. Secondary veins semicraspedodromous and uniform in angle of attachment of spacing. Intersecondary veins present. Intercostal tertiaries are random reticulate. Higher order venation indistinct. Teeth are shallow, irregular, and glandular. Possibly cf. Prunus sp.

Distribution at Falkland site

Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP331?

Falkland Specimens:

RYS06-0016, RYS06-0029, RYS06-0460, RYS06-0709, RYS06-0935, RYS06-0984, RYS07-0183, RYS07-0196, RYS07-0535, RYS07-0744, RYS07-0900, RYS07-0903

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	mesophyll 1	Base Angle	obtuse
			Apex Angle	acute
Laminar Shape	elliptic	ovate	Base Shape	convex, cuneate
Laminar Symmetry	symmetrical	L:W Ratio 2.1-2.6:1	Apex Shape	acuminate
Base Symmetry	symmetrical to occasionally asymmetrical		Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	uniform	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	not visible
2° attachment	decurrent	Vein frequency	not visible

3° to 5°

3° Vein Category	random reticulate	Epimedial3°	not visible
3° Vein Course	not applicable	Epimedial3° proximal course	not visible
3° Angle to 1°	not applicable	Epimedial3° distal course	not visible
3° Vein Angle Variability	not applicable	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cc/cv, st/cv	Principal vein	not visible
Sinus	angular	Termination	not visible
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	cf. Spiraea sp.	Morphotype #	FL040

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Rosaceae	Genus	*cf. Spiraea sp.*	Type spec. #	RYS06-0733

PHOTO

Description of morphotype:

Small obovate to elliptic leaf with rounded to emarginate apex. Lamina is symmetrical to slightly asymmetrical. Primary venation is pinnate. Secondary venation festooned semicraspedodromous. Intersecondaries present. Intercostal tertiaries irregular reticulate. Quaternaries freely ramifying. Teeth are regular, serrate, and closely spaced with simple apices. Sinuses rounded to angular.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0733
RYS07-0242
RYS07-0801

Leaf Architecture - Dicots Only

LEAF

Laminar Size	nanophyll	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 1	microphyll 2	Base Angle	acute
			Apex Angle	obtuse
Laminar Shape	obovate	elliptic	Base Shape	convex / cuneate
Laminar Symmetry	symmetrical	L:W Ratio 1.8:1	Apex Shape	rounded / emarginate
Base Symmetry	symmetrical		Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	festooned semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	parallel to major secondary
2° attachment	excurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	mixed
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	dichotomizing (fevs)
Exterior tertiary course	looped	5° Vein Category	not applicable

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	8	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cc/cv st/cv	Principal vein	present
Sinus	rounded to angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Incertae sedis			Morphotype #	FL041
Major Plant Group	DIC	Organ Type	Reproductive	Plant Family	
Genus		Type spec. #	RYS06-0214		

PHOTO

Description of morphotype:

Small flower, 5 mm in diameter, with five petals (or sepals).

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP129?

Falkland Specimens:

RYS06-0214

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Florissantia quilchenensis			Morphotype #	FL042
Major Plant Group	DIC	Organ Type	Reproductive	Plant Family	Malvaceae
Genus	*Florissantia*	Type spec. #	RYS07-0084		

PHOTO

Description of morphotype:

Pentamerous flower, synsepalous (varying in degrees of lobation, but united along at least 50% of length), ~3-4 cm in diameter. Calyx venation is distinct, with primary veins radiating out from the centre, occasionally branching, forming loops near the margin, joined by cross veins that form a reticulate net over the surface of the calyx.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☒
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP111
MB305

Falkland Specimens:

RYS06-0085, RYS06-0170, RYS06-0219, RYS06-0258, RYS06-0344, RYS06-0490, RYS06-0813, RYS06-0853, RYS06-0890, RYS06-0915, RYS07-0084, RYS07-0175, RYS07-0179, RYS07-0717, RYS07-0774, RYS07-0832, RYS07-0849, RYS07-0857, RYS07-0865, RYS07-0866, RYS07-0908, RYS07-0910, RYS07-0911, RYS07-0919, RYS07-0937, RYS07-0938, RYS07-0950, RYS08-0042

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Fagus langevinii	Morphotype #	FL044

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Fagaceae	Genus	*Fagus*	Type spec. #	RYS07-0877

PHOTO

Description of morphotype:

Elliptic to ovate leaf with large, simple crenate or serrate teeth with rounded sinus. Leaf is microphyll to notophyll but typically notophyll. Primary venation is pinnate. Secondary venation craspedodromous. Secondaries depart the midrib at fairly uniform angle (opposite to slightly off-set), are regularly spaced, and follow a straight course to the tooth apex. 9-12 pairs of secondaries present with no obvious exmedial secondary branches. Teeth are large, simple, and either crenate, or with a sharp tip.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP154
RP217
MB034

Falkland Specimens:

RYS06-0166, RYS06-0359, RYS06-0775, RYS06-0897, RYS06-1047, RYS07-0171, RYS07-0200, RYS07-0218, RYS07-0243, RYS07-0355, RYS07-0856, RYS07-0877

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	mesophyll 1	Base Angle	obtuse
			Apex Angle	acute
Laminar Shape	elliptic	ovate	Base Shape	convex
Laminar Symmetry	symmetrical		Apex Shape	convex; straight
L:W Ratio	2.1-2.4:1		Margin Type	crenate; serrate
Base Symmetry	not visible		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	straight; sinuous	Epimedial3° proximal course	obtuse to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	alternate percurrent
Exterior tertiary course	not visible	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	1-2	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cv/cv; cv/fl; cc/cv; cc/fl	Principal vein	present
Sinus	rounded	Termination	proximal flank of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL045

Major Plant Group		Organ Type	Seeds	Plant Family		Genus		Type spec. #	RYS07-0850

PHOTO

Description of morphotype:

Small seeds (<1 mm in diameter). Found scattered or in some cases aggregated. Individual seeds round to ellipsoid in shape.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0007, RYS06-0045, RYS06-0200, RYS06-0225, RYS06-0313, RYS06-0343, RYS06-0370, RYS06-0597, RYS07-0154, RYS07-0275, RYS07-0331, RYS07-0788, RYS07-0800, RYS07-0810, RYS07-0850

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL047

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0545

PHOTO

Description of morphotype:

Large (mesophyll) elliptic leaf with entire margin. Apex is acute and convex. Base is not preserved, but appears convex. Primary venation is imperfectly suprabasal acrodromous (lateral veins reaching 2/3 of the way towards apex). Secondary venation eucamptodromous or weak brochidodromous (venation indistinct at margin, but not appearing to form obvious loops). Agrophic veins and interior secondaries present. Intercostal tertiaries form a coarse, irregular mesh. In general, venation is rather poorly preserved.

Distribution at Falkland site

- ☐ Unit 3
- ☐ Unit 2
- ☒ Unit 1
- ☐ Scree

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0545

Leaf Architecture - Dicots Only

LEAF

Laminar Size	mesophyll		Petiolar Attach.	marginal	
Clamp Size	mesophyll 2		Base Angle	not visible	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	convex	
Laminar Symmetry	symmetrical	L:W Ratio: 1.9:1	Apex Shape	convex	
Base Symmetry	not visible		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	suprabasal acrodromous	Interior secondaries	present
Agrophic Veins	simple	Minor 2° course	simple brochidodromous
# of Basal Veins	not visible	Inter-2° Veins	not visible
2° Vein Category	eucamptodromous	Length	not visible
2° Vein Spacing	not visible	Proximal course	not visible
2° Vein Angle	not visible	Distal course	not visible
2° attachment	excurrent	Vein frequency	not visible

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	reticulate
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	not visible	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL049

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0156

PHOTO

Description of morphotype:

Narrowly elliptic notophyll leaf with irregularly crenate margin. Base of leaf is not preserved. Apex is straight with an acute angle. Primary venation is pinnate. Major secondaries are craspedodromous with uniform spacing and angle of attachment, straight to slightly convex. Higher order venation indistinct. Teeth are very irregular, with margin appearing almost entire in places. Teeth are shallow and crenate.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0156

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	marginal	
Clamp Size	mesophyll 1		Base Angle	not visible	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio: >2<3:1	Apex Shape	straight	
Base Symmetry	not visible		Margin Type	crenate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	not visible	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FV EI NI EN RS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◯ yes ◉ no
Teeth/cm	4	Teeth round	◉ yes ◯ no
Spacing	irregular	Teeth acute	◯ yes ◉ no
Shape	cv/cv st/cv cv/fl	Principal vein	present
Sinus	angular	Termination	marginal
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	MORPHOTYPE NAME	Acer sp. 1		MORPHOTYPE #	FL050
MAJOR PLANT GROUP	DIC	ORGAN TYPE	Leaf	PLANT FAMILY	Sapindaceae
GENUS	*Acer*	TYPE SPEC. #	RYS07-0785		

PHOTO

Description of morphotype:

Notophyll palmately lobed leaf. Lamina ovate and symmetrical with acute apex. Primary venation basal actinodromous with agrophic veins. Secondary venation craspedodromous, veins following a relatively straight course from midrib to margin, departing the midrib opposite and at acute angle (~25 degrees). Interior secondaries are present. Teeth are compound, irregular to regular in spacing with angular sinus and simple apices.

Distribution at Falkland site

- UNIT 3 ☒
- UNIT 2 ☐
- UNIT 1 ☐
- SCREE ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0143
RYS07-0785

Leaf Architecture - Dicots Only

LEAF

LAMINAR SIZE	notophyll	PETIOLAR ATTACH.	marginal
CLAMP SIZE	mesophyll 1	BASE ANGLE	obtuse
LAMINAR SHAPE	ovate	APEX ANGLE	acute
LAMINAR SYMMETRY	symmetrical	BASE SHAPE	not visible
L:W RATIO	1.4:1	APEX SHAPE	straight
BASE SYMMETRY	not visible	MARGIN TYPE	serrate
		LOBATION	palmately

1° to 2°

1° VEIN CATEGORY	basal actinodromous	INTERIOR SECONDARIES	present
AGROPHIC VEINS	present	MINOR 2° COURSE	craspedodromous
# OF BASAL VEINS	not visible	INTER-2° VEINS	absent
2° VEIN CATEGORY	craspedodromous	LENGTH	not applicable
2° VEIN SPACING	increasing toward base	PROXIMAL COURSE	not applicable
2° VEIN ANGLE	uniform	DISTAL COURSE	not applicable
2° ATTACHMENT	excurrent	VEIN FREQUENCY	not applicable

3° to 5°

3° VEIN CATEGORY	alternate percurrent	EPIMEDIAL3°	alternate percurrent
3° VEIN COURSE	not applicable	EPIMEDIAL3° PROXIMAL COURSE	acute to midvein
3° ANGLE TO 1°	obtuse	EPIMEDIAL3° DISTAL COURSE	basiflexed
3° VEIN ANGLE VARIABILITY	inconsistent	4° VEIN CATEGORY	irregular reticulate
EXTERIOR TERTIARY COURSE	looped	5° VEIN CATEGORY	dichotomizing (fevs)

FINE VEINS

AREOLATION	moderately developed
F.E.V.S	not visible
MARGINAL ULTIMATE VENATION	not visible

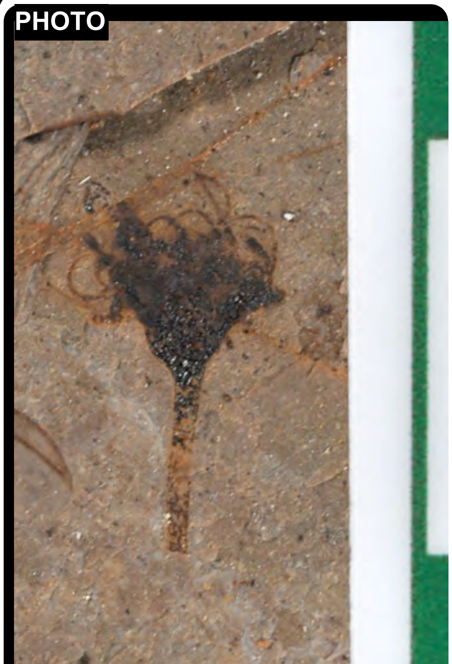
TEETH

# OF ORDERS	2	TEETH CLOSE	◉ yes ○ no
TEETH/CM	3	TEETH ROUND	○ yes ◉ no
SPACING	irregular	TEETH ACUTE	◉ yes ○ no
SHAPE	fl/fl, cv/cv, st/cv	PRINCIPAL VEIN	present
SINUS	angular	TERMINATION	at apex of tooth
APEX	simple	ACCESORY VEIN	not visible

Falkland (BC) Flora

Morphotype Name	Trochodendron sp.
Morphotype #	FL051
Major Plant Group	DIC
Organ Type	Reproductive
Plant Family	Trochodendraceae
Genus	*Trochodendron*
Type spec. #	RYS06-0114

PHOTO



Description of morphotype:

Fruit in the shape of an inverted triangle, 4 mm wide at apex, and 3 mm in length, with persistent styles visible. Peduncle ~4 mm long. This type appears to more closely resemble the smaller Republic type of Trochodendron sp. fruit, rather than the more robust T. drachukii found at McAbee.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP260
MB319

Falkland Specimens:

RYS06-0114

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Pseudolarix sp.		Morphotype #	FL052
Major Plant Group	CON	Organ Type	Leaf	Plant Family	Pinaceae
Genus	*Pseudolarix*	Type spec. #	RYS07-0802		

PHOTO

Description of morphotype:

Needle is 5+ cm long with broad midrib, widest in the middle, up to 4 mm, narrowing at both ends.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP135
RP136
MB016
MB014

Falkland Specimens:

RYS06-0058, RYS06-0176, RYS06-0233, RYS06-0420, RYS06-0457, RYS06-0736, RYS06-0754, RYS06-0771, RYS06-0817, RYS06-0927, RYS06-0990, RYS06-1041, RYS06-1049, RYS07-0227, RYS07-0268, RYS07-0388, RYS07-0589, RYS07-0593, RYS07-0597, RYS07-0676, RYS07-0714, RYS07-0728, RYS07-0802

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◯ yes ◯ no
Teeth/cm		Teeth round	◯ yes ◯ no
Spacing		Teeth acute	◯ yes ◯ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Joffrea sp.	Morphotype #	FL053

Major Plant Group	DIC	Organ Type	Fruit	Plant Family	Cercidiphyllaceae	Genus	*Joffrea*	Type spec. #	RYS06-0337

PHOTO

Description of morphotype:

Infructescence. Fruits (follicles) are attached to stem which appears jointed at the point of attachment. Fruits attached alternately. Fruits are approximately 8 mm long by 4 mm wide and elliptic in shape. Surface of fruits appears striated.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP080
MB328

Falkland Specimens:

RYS06-0337

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

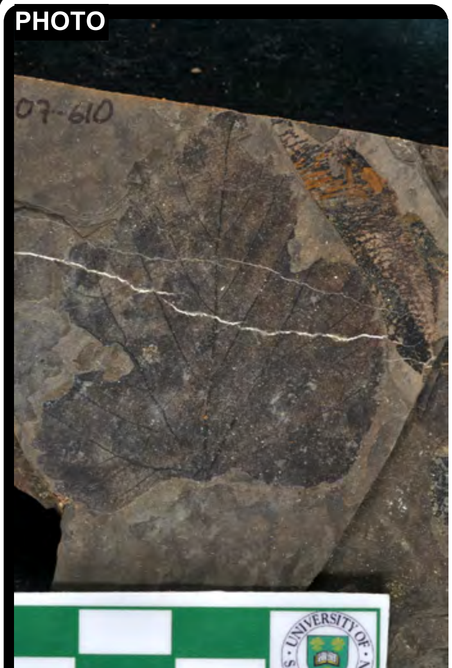
Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL054
Major Plant Group: DIC	Organ Type: Leaf	Plant Family:	Genus:	Type spec. #: RYS07-0610

PHOTO



Description of morphotype:

Microphyll toothed leaf with compound agrophic veins. Lamina is symmetrical with a cordate base and convex apex. Lamina is unlobed, although appears to have a tendency towards palmate lobation (due to preservation/damage to lamina). Primary venation is pinnate with strong compound agrophic veins (appears actinodromous because of agrophic veins, but no clear lateral primaries are present). Secondary venation is craspedodromous with spacing increasing proximally, and angle of attachment uniform. Margin is indistinct due to preservation, but is toothed. Possibly Acer sp.

Distribution at Falkland site

Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP209?

Falkland Specimens:

RYS06-0145
RYS07-0610

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal
Clamp Size	microphyll 2	microphyll 3	Base Angle	wide obtuse; Apex Angle: obtuse
Laminar Shape	ovate	elliptic	Base Shape	cordate
Laminar Symmetry	symmetrical	L:W Ratio: 1.1:1	Apex Shape	convex
Base Symmetry	symmetrical		Margin Type	serrate; Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	compound	Minor 2° course	craspedodromous
# of Basal Veins	5	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	opposite percurrent
3° Vein Course	convex	straight	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	irregular reticulate
Exterior tertiary course	not visible		5° Vein Category	irregular reticulate

FINE VEINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	not visible	Teeth Close	yes
Teeth/cm	not visible	Teeth Round	no
Spacing	not visible	Teeth Acute	yes
Shape	st/st	Principal vein	not visible
Sinus	angular	Termination	not visible
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Taxodium dubium					Morphotype #	FL055
Major Plant Group	CON	Organ Type	Leaf	Plant Family	Cupressaceae	Genus	*Taxodium*
Type spec. #	RYS06-0425						

PHOTO

Description of morphotype:

Needles narrower and longer than Metasequoia, and depart midrib at more acute angle. Needles petiolate with decurrent base.

Distribution at Falkland site

Unit 3	☐
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0361, RYS06-0425, RYS06-0569, RYS06-0672, RYS06-0674, RYS06-0957, RYS07-0033, RYS07-0553, RYS07-0567

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL056

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0195

PHOTO

Description of morphotype:

Notophyll leaf with large crenate teeth and a slightly acuminate apex. Lamina is elliptic to oblong and symmetrical. Primary venation is pinnate. Secondary venation craspedodromous. Secondary vein angle abruptly increases at base. Higher order venation indistinct. Teeth have long basal side, and are rounded (crenate) to slightly serrate. Basal 1/3 of leaf has few to no teeth. Teeth become closer together and more serrate apically.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP043?

Falkland Specimens:

RYS06-0195
RYS06-0275

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 1	Base Angle	obtuse	Apex Angle	acute
Laminar Shape	elliptic		Base Shape	convex		
Laminar Symmetry	symmetrical	L:W Ratio 2.1:1	Apex Shape	acuminate	convex	
Base Symmetry	not visible		Margin Type	serrate	crenate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	not visible
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cv/cv st/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL057
Major Plant Group: DIC	Organ Type: Leaf	Plant Family:	Genus:	Type spec. #: RYS07-0284

PHOTO

Description of morphotype:

Shallowly lobed ovate leaf with simple agrophic veins and cordate base. Petiole often bent. Laminar size microphyll to notophyll, leaf blade symmetrical. Margin shallowly serrate to crenate. Primary venation basal actinodromous with 3 basal veins. Major secondaries semicraspedodromous with irregular spacing and decurrent attachment. Interior secondaries are present. Minor secondary course is simple brochidodromous. Intersecondaries are present.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP225?

Falkland Specimens:

RYS06-0057
RYS06-0336
RYS07-0284
RYS07-0292
RYS07-0362

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal
Clamp Size	mesophyll 1		Base Angle	obtuse; Apex Angle: acute
Laminar Shape	ovate		Base Shape	cordate
Laminar Symmetry	symmetrical	L:W Ratio: 1.4-1.6:1	Apex Shape	convex; straight
Base Symmetry	symmetrical		Margin Type	crenate; serrate; Lobation: palmately

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	present
Agrophic Veins	simple	Minor 2° course	simple brochidodromous
# of Basal Veins	3	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	not visible

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial3°	alternate percurrent
3° Vein Course		Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	inconsistent	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	no
Teeth/cm	2	Teeth round	yes
Spacing	irregular	Teeth acute	yes
Shape	cv/cv st/cv	Principal vein	present
Sinus	angular	Termination	distal flank of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Metasequoia occidentalis	Morphotype #	FL059

Major Plant Group	CON	Organ Type	Reproductive	Plant Family	Cupressaceae	Genus	*Metasequoia*	Type spec. #	RYS06-0404

PHOTO

Description of morphotype:

Ovulate cone borne on long, naked peduncle. Cone scales decussately arranged.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes RP=Republic MB=McAbee	RP284 MB210

Falkland Specimens:

RYS06-0404
RYS06-0474
RYS06-1052
RYS07-0361

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.		
Clamp Size			Base Angle		Apex Angle
Laminar Shape			Base Shape		
Laminar Symmetry		L:W Ratio	Apex Shape		
Base Symmetry			Margin Type		Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora | **Morphotype Name:** Incertae sedis | **Morphotype #:** FL060

Major Plant Group: DIC | **Organ Type:** Reproductive | **Plant Family:** | **Genus:** | **Type spec. #:** RYS06-0090

PHOTO

Description of morphotype:

Possibly a leaf-like invulucre with fruiting structures, or a small leaf with galls. Invulucre or leaf is small (microphyll) ~4 cm long by ~1 cm wide and ovate, appearing to subtend a pair of fruiting structures (or galls). Structures are spherical, ~7 mm in diameter with a reticulate surface.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0090

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Sequoia affinis							Morphotype #	FL061
Major Plant Group	CON	Organ Type	Reproductive	Plant Family	Cupressaceae	Genus	*Sequoia*	Type spec. #	RYS06-0042

PHOTO

Description of morphotype:

Staminate cones, terminal on short lateral branches with scales.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0042
RYS07-0113

Leaf Architecture - Dicots Only

LEAF

Laminar Size
Clamp Size
Laminar Shape
Laminar Symmetry
L:W Ratio
Base Symmetry
Petiolar Attach.
Base Angle
Apex Angle
Base Shape
Apex Shape
Margin Type
Lobation

1° to 2°

1° Vein Category
Agrophic Veins
# of Basal Veins
2° Vein Category
2° Vein Spacing
2° Vein Angle
2° attachment
Interior secondaries
Minor 2° course
Inter-2° Veins
Length
Proximal course
Distal course
Vein frequency

3° to 5°

3° Vein Category
3° Vein Course
3° Angle to 1°
3° Vein Angle Variability
Exterior tertiary course
Epimedial3°
Epimedial3° proximal course
Epimedial3° distal course
4° Vein Category
5° Vein Category

FINE VEINS

Areolation
F.E.V.s
Marginal Ultimate Venation

TEETH

# of Orders
Teeth/cm
Spacing
Shape
Sinus
Apex
Teeth Close ○ yes ○ no
Teeth round ○ yes ○ no
Teeth acute ○ yes ○ no
Principal vein
Termination
Accesory vein

Falkland (BC) Flora

Morphotype Name	Abies milleri	Morphotype #	FL062
Major Plant Group	CON	Organ Type	Reproductive
Plant Family	Pinaceae	Genus	*Abies*
Type spec. #	RYS06-0967		

PHOTO

Description of morphotype:

Cone scale is 2.2 cm wide at widest point (near apical margin) and 2.5 cm long from attachment base to apical margin. Scale is deltoid in shape with rounded edges and cuneate base.

Distribution at Falkland site

Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP115
MB201

Falkland Specimens:

RYS06-0967, RYS06-1011, RYS06-1033, RYS07-0478, RYS07-0858, RYS08-0060, RYS08-0061

Leaf Architecture - Dicots Only

LEAF: Laminar Size; Clamp Size; Laminar Shape; Laminar Symmetry; L:W Ratio; Base Symmetry; Petiolar Attach.; Base Angle; Apex Angle; Base Shape; Apex Shape; Margin Type; Lobation

1° to 2°: 1° Vein Category; Agrophic Veins; # of Basal Veins; 2° Vein Category; 2° Vein Spacing; 2° Vein Angle; 2° attachment; Interior secondaries; Minor 2° course; Inter-2° Veins; Length; Proximal course; Distal course; Vein frequency

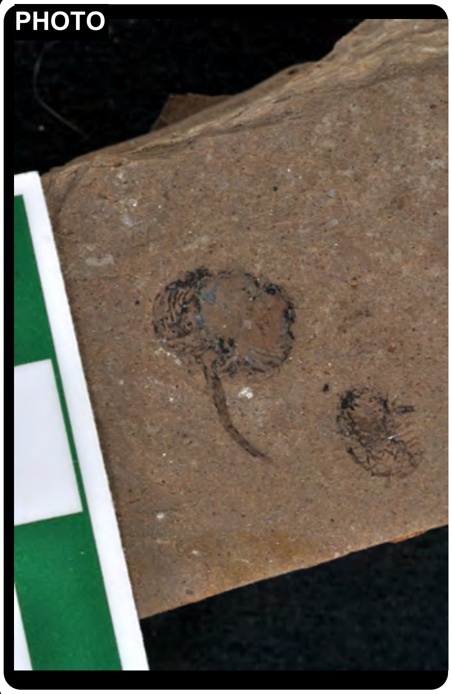
3° to 5°: 3° Vein Category; 3° Vein Course; 3° Angle to 1°; 3° Vein Angle Variability; Exterior tertiary course; Epimedial3°; Epimedial3° proximal course; Epimedial3° distal course; 4° Vein Category; 5° Vein Category

FINE VEINS: Areolation; F.E.V.s; Marginal Ultimate Venation

TEETH: # of Orders; Teeth/cm; Spacing; Shape; Sinus; Apex; Teeth Close ◌ yes ◌ no; Teeth round ◌ yes ◌ no; Teeth acute ◌ yes ◌ no; Principal vein; Termination; Accesory vein

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL063
Major Plant Group		Organ Type	Reproductive	Plant Family
Genus		Type spec. #	RYS06-0856	

PHOTO



Description of morphotype:

Infructescence, with one isolated fruit (?) detached. Fruiting structure is 10 mm wide by 5 mm long, terminal on a peduncle ~7 mm long. Based on detached fruit, whole structure may be composed of 4 individual reniform fruits with a ribbed and/or ciliate surface.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0856

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL064
Major Plant Group: CON	Organ Type: Leaf	Plant Family:	Genus:	Type spec. #: RYS06-0811

PHOTO

Description of morphotype:

Leaf is needle-like but broad, at least 5 cm long, and 0.6 cm wide. Acute apex, slightly curved, broadest in the middle with a prominent midrib.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0811

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Alnus parvifolia (catkin)	Morphotype #	FL065

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family	Betulaceae	Genus	*Alnus*	Type spec. #	RYS08-0029

PHOTO

Description of morphotype:

Pistillate catkins, terminal on peduncle, typically occurring in groups of 3. Individual structures ~1.1 to 1.5 (up to 2) cm long and ~0.6 to 0.8 cm wide.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP089
MB315

Falkland Specimens:

RYS06-0083, RYS06-0791, RYS06-1032, RYS07-0231, RYS07-0398, RYS07-0404, RYS07-0418, RYS07-0517, RYS07-0542, RYS07-0873, RYS07-0925, RYS07-0926, RYS07-0944, RYS07-0956, RYS07-0960, RYS08-0027, RYS08-0029, RYS08-0032, RYS08-0043

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Acer sp. 2 (samara)	Morphotype #	FL066

Major Plant Group	DIC	Organ Type	Fruit	Plant Family	Sapindaceae	Genus	*Acer*	Type spec. #	RYS07-0559

PHOTO

Description of morphotype:

Acer samara. Attachment scar indicates that the "back" of the wing is marginal (rather than medial as in Deviacer). This morphotype has a broader wing than FL095 with a more open pattern of venation. The largest samara has a seed body 8 mm x 6 mm and a wing 25 mm x 14 mm and the smallest (complete) wing is 15 mm x 11 mm.

Distribution at Falkland site

Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP277?
MB330?

Falkland Specimens:

RYS07-0559
RYS07-0780
RYS07-0876
RYS08-0036

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL067

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0826

PHOTO

Description of morphotype:

Notophyll leaf with serrate margin. Elliptic to ovate in shape and symmetrical. Apex is acute and convex. Base is obtuse and convex. Petiole ~1 cm long. Primary venation pinnate. Secondary venation is craspedodromous in apical part of lamina to semi-craspedodromous in lower half of leaf where angle of divergence from midrib abruptly increases, becoming almost perpendicular to midvein. Intercostal tertiaries are opposite percurrent. Teeth are regular to irregular with two orders of teeth. Teeth serrate to crenate.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0309, RYS06-0318, RYS06-0789, RYS06-0818, RYS06-0826, RYS07-0020

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	marginal	
Clamp Size	mesophyll 1	mesophyll 2	Base Angle	obtuse	Apex Angle: acute
Laminar Shape	elliptic	ovate	Base Shape	convex	
Laminar Symmetry	symmetrical	L:W Ratio: 1.6:1	Apex Shape	convex	
Base Symmetry	symmetrical		Margin Type	serrate, crenate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	opposite percurrent
3° Vein Course	sinuous	straight	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	alternate percurrent
Exterior tertiary course	terminating at margin		5° Vein Category	irregular reticulate

FINE VEINS

Areolation	well developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	○ yes ● no
Teeth/cm	3	Teeth Round	● yes ○ no
Spacing	regular	Teeth Acute	● yes ○ no
Shape	cv/cv, st/cv, st/fl, fl/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL068
Major Plant Group		Organ Type	Reproductive	Plant Family
Genus		Type spec. #	RYS06-0604	

PHOTO

Description of morphotype:

Possibly a carpel? Structure is 11 mm long and 3 mm wide at base. Basal portion is rounded, containing seed or ovule (?).

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0604

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Aesculus sp.	Morphotype #	FL069

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Sapindaceae	*Aesculus*	RYS06-0262

PHOTO

Description of morphotype:

Obovate leaf with finely serrate margin in upper half of leaf. Leaf is notophyll to mesophyll in size and narrows abruptly at the base. This is likely a leaflet of a compound leaf. Apex is acuminate. Primary venation is pinnate and secondary venation is semi-craspedodromous. Tertiaries numerous, opposite percurrent, convex near the midrib to straight exmedially. Tertiaries appear continuous as they depart the secondary veins opposite one another, continuing along the same course.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP213
MB067

Falkland Specimens:

RYS06-0019, RYS06-0247, RYS06-0262, RYS06-0266, RYS06-0609, RYS06-0760, RYS06-0909, RYS07-0448

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	mesophyll	Petiolar Attach.	marginal		
Clamp Size	mesophyll 1	mesophyll 2	Base Angle	not visible	Apex Angle	acute
Laminar Shape	obovate		Base Shape	not visible		
Laminar Symmetry	symmetrical	L:W Ratio 1.7:1	Apex Shape	acuminate		
Base Symmetry	not visible		Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	mixed
3° Vein Course	convex	straight	Epimedial3° proximal course	not applicable
3° Angle to 1°	obtuse		Epimedial3° distal course	not applicable
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	mixed percurrent
Exterior tertiary course	terminating at margin		5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	5	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	st/fl cc/fl cc/cv	Principal vein	present
Sinus	angular	Termination	distal flank of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Abies milleri			Morphotype #	FL074
Major Plant Group	CON	Organ Type	Leaf	Plant Family	Pinaceae
Genus	*Abies*	Type spec. #	RYS07-0665		

PHOTO

Description of morphotype:

Needles up to ~20 mm long and 1 mm wide, helically arranged. Needles depart the axis at a fairly wide angle. Leaf bases appear circular and twisted.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP122
MB006

Falkland Specimens:

RYS06-0796
RYS07-0550
RYS07-0665
RYS07-0838
RYS08-0020

Leaf Architecture - Dicots Only

LEAF			
Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS		TEETH			
Areolation		# of Orders		Teeth Close	◌ yes ◌ no
F.E.V.s		Teeth/cm		Teeth round	◌ yes ◌ no
Marginal Ultimate Venation		Spacing		Teeth acute	◌ yes ◌ no
		Shape		Principal vein	
		Sinus		Termination	
		Apex		Accesory vein	

Falkland (BC) Flora | Morphotype Name: Incertae sedis | Morphotype #: FL075

Major Plant Group: DIC | Organ Type: Reproductive | Plant Family: | Genus: | Type spec. #: RYS06-0024

PHOTO

Description of morphotype:

Small flower, approximately 0.9 cm wide by 0.5 cm tall, with 4 (or 5?) petals, narrowly elliptic to rounded with tapered ends, curving upwards. Each petal ~0.4 cm long. Pedicel ~0.5 cm long.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP130?

Falkland Specimens:

RYS06-0024
RYS06-0779

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL077

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0929

PHOTO

Description of morphotype:

Narrow ovate leaf with entire margin and brochidodromous secondaries. Lamina is slightly asymmetrical and chartaceous to coriaceous in texture. Margin is unlobed and entire. Apex is acute and straight to convex in shape. Base is not visible. Intermarginal secondary vein may be present. Primary venation is pinnate. Secondary venation is brochidodromous and intersecondaries are present. Intercostal tertiaries are irregular reticulate. Higher order venation indistinct.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0749
RYS06-0929
RYS07-0614

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll			Petiolar Attach.	not visible		
Clamp Size	microphyll 3			Base Angle	not visible	Apex Angle	acute
Laminar Shape	ovate			Base Shape	not visible		
Laminar Symmetry	asymmetrical	L:W Ratio	3.5:1	Apex Shape	straight	convex	
Base Symmetry	not visible			Margin Type	entire	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	strong
2° Vein Category	brochidodromous	Length	>50% of subjacent secondary
2° Vein Spacing	not visible	Proximal course	parallel to major secondaries
2° Vein Angle	not visible	Distal course	parallel to major secondary
2° attachment	decurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	reticulate
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

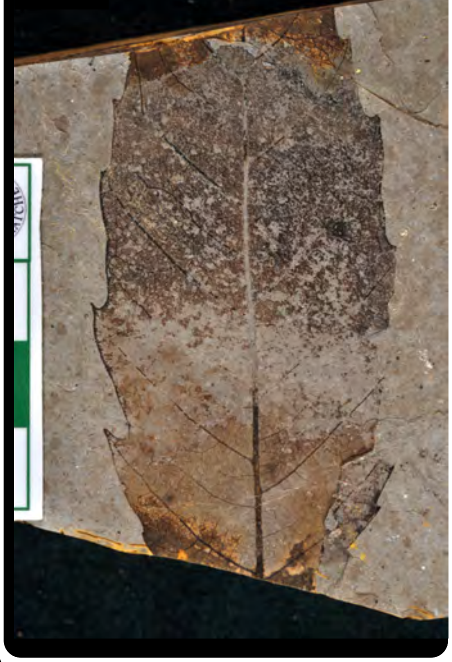
TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	?Quercus sp.	Morphotype #	FL079

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Fagaceae	Genus	*?Quercus*	Type spec. #	RYS07-0191

PHOTO



Description of morphotype:

Elliptic, narrow leaf with widely spaced teeth with rounded sinuses. Primary venation is pinnate and secondary venation is craspedodromous. Morphotype is distinguished from FL044 by the presence of intersecondary veins. Further work may be needed to determine if this is a true Quercus, or other castaneoid or quercoid.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0093
RYS07-0191

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	not visible	
Clamp Size	microphyll 3	mesophyll 1	Base Angle	not visible	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio: 2.3:1	Apex Shape	straight	convex
Base Symmetry	not visible		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	not visible	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	parallel to major secondary
2° attachment	excurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial 3°	mixed percurrent
3° Vein Course	sinuous	Epimedial 3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial 3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	opposite percurrent
Exterior tertiary course	looped	5° Vein Category	irregular reticulate

FINER VEINS

Areolation	well developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	1	Teeth round	○ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cc/fl cc/cv	Principal vein	present
Sinus	rounded	Termination	at apex of tooth
Apex	spinose	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	?Salicaceae sp. 2	Morphotype #	FL080

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Salicaceae	Genus		Type spec. #	RYS07-0455

PHOTO

Description of morphotype:

Unlobed microphyll leaf with very small, sharp teeth. Base and apex angle acute. Leaf is narrow with pinnate primary venation and semi-craspedodroumous secondary veins with strong intersecondary veins present.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☐
Unit 1	☒
Scree	☐

Similar Morphotypes RP=Republic MB=McAbee	MB031?

Falkland Specimens:

RYS07-0455
RYS07-0754

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 3		Base Angle	acute	Apex Angle: acute
Laminar Shape	obovate	elliptic	Base Shape	convex	cuneate
Laminar Symmetry	symmetrical	L:W Ratio 3.4:1	Apex Shape	not visible	
Base Symmetry	symmetrical		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	craspedodromous
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	smoothly decreasing towards base	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	>1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	reticulate
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	1-branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	3-4	Teeth round	○ yes ◉ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cv/cv cc/cv	Principal vein	not visible
Sinus	angular	Termination	not visible
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Ulmus okanaganensis type 1	Morphotype #	FL081

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Ulmaceae	Genus	*Ulmus*	Type spec. #	RYS07-0736

PHOTO

Description of morphotype:

Oblong to elliptic leaf with rounded teeth; teeth simple or with small secondary teeth. Laminar size microphyll to mesophyll but predominantly notophyll. Venation is pinnate with craspedodromous secondaries with uniform spacing, angle of attachment more obtuse at the base, departing the midvein opposite to sub-opposite at the base changing to alternate near the apex. Laminar base cordate and slightly asymmetrical. This is Ulmus okanaganensis leaf type 1 of Denk and Dillhoff (2005) interpreted as "sucker shoot" leaves. See FL021 for leaf type 2. FL021 and FL081 treated as single morphotype in all analyses of diversity and climate.

Distribution at Falkland site		Similar Morphotypes	
	Unit 3 ☒	RP=Republic	RP050
	Unit 2 ☒	MB=McAbee	MB038
	Unit 1 ☒		
	Scree ☒		

Falkland Specimens:

RYS06-0274, RYS06-0651, RYS07-0127, RYS07-0164, RYS07-0202, RYS07-0363, RYS07-0656, RYS07-0736, RYS07-0767, RYS07-0773, RYS07-0827, RYS08-0046

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll		Petiolar Attach.	marginal		
Clamp Size	microphyll 2	mesophyll 1		Base Angle	obtuse	Apex Angle	acute
Laminar Shape	oblong	elliptic		Base Shape	cordate	convex	
Laminar Symmetry	symmetrical	L:W Ratio	2.0-2.4:1	Apex Shape	acuminate	convex	
Base Symmetry	basal extension asymmetrical			Margin Type	crenate	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial3°	opposite percurrent
3° Vein Course	sinuous	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	basiflexed
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	alternate percurrent
Exterior tertiary course	terminating at margin	5° Vein Category	dichotomizing (fevs)

FINE VEINS

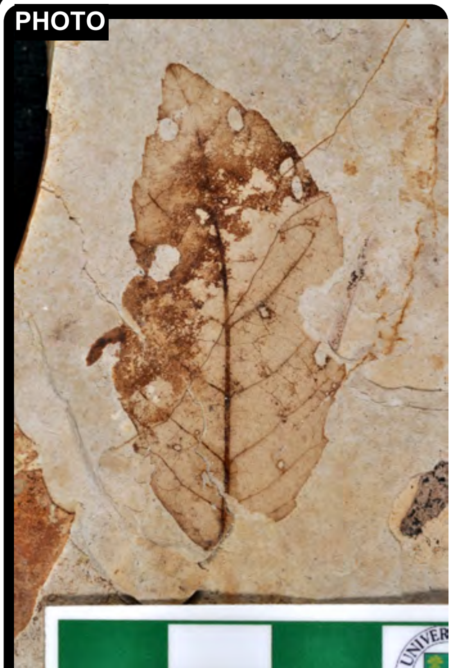
Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	○ yes ◉ no
Teeth/cm	3	Teeth Round	◉ yes ○ no
Spacing	regular	Teeth Acute	◉ yes ○ no
Shape	cv/cv fl/fl cc/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Incertae sedis		Morphotype #	FL082
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	
Genus		Type spec. #	RYS06-0724		

PHOTO



Description of morphotype:

Microphyll elliptic leaf with asymmetrical lamina and compound teeth. Apex angle is acute and straight to slightly convex in shape. Base is obtuse and convex. Primary venation is pinnate. Secondary venation is craspedodromous with uniform spacing and angle of attachment. Agrophic veins and intersecondary veins absent. Intercostal tertiaries are mixed percurrent. Teeth are shallowly serrate to crenate and compound, with two orders of teeth. Possibly Alnus sp.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0724
RYS07-0377

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 2	microphyll 3	Base Angle	obtuse	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	convex	
Laminar Symmetry	asymmetrical	L:W Ratio: 2.1-2.5:1	Apex Shape	convex	straight
Base Symmetry	symmetrical		Margin Type	serrate, crenate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	mixed opp/alt		Epimedial 3°	mixed percurrent
3° Vein Course	convex	sinuous	Epimedial 3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial 3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	mixed percurrent
Exterior tertiary course	terminating at margin		5° Vein Category	not visible

FINE VEINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders	2	Teeth Close	○ yes ◉ no
Teeth/cm	3	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cv/fl, cv/cv, fl/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL084

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0918

PHOTO

Description of morphotype:

Narrow elliptic microphyll leaf with smoothly crenate to undulate margin. Leaf chartaceous in texture. Apex is acute and convex in shape. Base is not visible. Primary venation is pinnate. Secondary venation is semicraspedodromous and uniform in spacing and angle of attachment. Secondaries depart midrib at an acute angle but quickly change to a wide angle. Intersecondary veins are present. Tertiary veins are opposite and alternate percurrent. Teeth are simple and crenate, irregularly spaced, and shallower on one side of the margin. Possibly Fagaceae sp.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0918

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	not visible	
Clamp Size	microphyll 2		Base Angle	not visible	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio: >3.6:1	Apex Shape	convex	
Base Symmetry	not visible		Margin Type	crenate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	uniform	Proximal course	perpendicular to midvein
2° Vein Angle	uniform	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	alternate percurrent	Epimedial 3°	opposite percurrent
3° Vein Course	sinuous	convex	Epimedial 3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial 3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing basally		4° Vein Category	irregular reticulate
Exterior tertiary course	looped		5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth Round	◉ yes ○ no
Spacing	irregular	Teeth Acute	○ yes ◉ no
Shape	cv/cv	Principal vein	present
Sinus	rounded	Termination	marginal
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis		Morphotype #	FL086
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	
Genus		Type spec. #	RYS06-0408		

PHOTO

Description of morphotype:

Notophyll obovate leaf with serrate teeth with rounded sinuses. Lamina is symmetrical and unlobed. Petiole is stout with a pulvinate base. Primary venation is pinnate. Secondary venation is semicraspedodromous and uniform in spacing and angle of attachment. Intersecondary veins and agrophic veins absent. Intercostal tertiaries are opposite percurrent. Higher order venation indistinct. Teeth are rather widely spaced, simple, and with rounded sinuses.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes
RP=Republic
MB=McAbee

MB086?

Falkland Specimens:

RYS06-0408

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	Petiolar Attach.	marginal
Clamp Size	mesophyll 1	Base Angle	obtuse
Laminar Shape	obovate	Apex Angle	not visible
Laminar Symmetry	symmetrical	Base Shape	convex
L:W Ratio	>1<2:1	Apex Shape	not visible
Base Symmetry	symmetrical	Margin Type	serrate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	sinuous	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing basally	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◯ yes ◉ no
Teeth/cm	2	Teeth round	◉ yes ◯ no
Spacing	regular	Teeth acute	◉ yes ◯ no
Shape	fl/fl cc/fl cv/fl st/fl	Principal vein	present
Sinus	rounded	Termination	marginal
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Ribes sp.	Morphotype #	FL088

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Grossulariaceae	*Ribes*	RYS08-0001

PHOTO

Description of morphotype:

Palmately lobed leaf, nanophyll to notophyll in size but predominantly microphyll, with a cordate base. Leaf has broad, rounded teeth (crenate margin). Primary venation basal actinodromous with compound agrophic veins. Secondaries are craspedodromous. Leaf is typically poorly preserved with little detail of venation visible (membranaceous texture), particularly near the margin.

Distribution at Falkland site

Unit	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP200
MB039

Falkland Specimens:

RYS06-0846, RYS06-1007, RYS07-0015, RYS07-0376, RYS07-0794, RYS07-0883, RYS08-0001, RYS08-0024, RYS08-0038

Leaf Architecture - Dicots Only

LEAF

Laminar Size	nanophyll	notophyll
Clamp Size	microphyll 1	microphyll 3
Laminar Shape	elliptic	
Laminar Symmetry	symmetrical	L:W Ratio 0.6-1:1
Base Symmetry	symmetrical	
Petiolar Attach.	marginal	
Base Angle	obtuse	Apex Angle: obtuse
Base Shape	cordate	
Apex Shape	convex	
Margin Type	crenate	Lobation: palmately

1° to 2°

1° Vein Category	basal actinodromous
Agrophic Veins	compound
# of Basal Veins	8
2° Vein Category	craspedodromous
2° Vein Spacing	increasing toward base
2° Vein Angle	uniform
2° attachment	decurrent
Interior secondaries	present
Minor 2° course	craspedodromous
Inter-2° Veins	absent
Length	not applicable
Proximal course	not applicable
Distal course	not applicable
Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	
3° Vein Course	convex	chevron
3° Angle to 1°	acute	
3° Vein Angle Variability	not visible	
Exterior tertiary course	terminating at margin	
Epimedial3°	opposite percurrent	
Epimedial3° proximal course	acute to midvein	
Epimedial3° distal course	basiflexed	
4° Vein Category	not visible	
5° Vein Category	not visible	

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	
Teeth/cm	2-3	
Spacing	irregular	
Shape	cv/cv	fl/fl
Sinus	angular	
Apex	simple	
Teeth Close	◉ yes	○ no
Teeth Round	◉ yes	○ no
Teeth Acute	○ yes	◉ no
Principal vein	present	
Termination	sinus	
Accesory vein	not visible	

Falkland (BC) Flora	Morphotype Name	Picea sp.	Morphotype #	FL089
Major Plant Group: CON	Organ Type: Axis	Plant Family: Pinaceae	Genus: *Picea*	Type spec. #: RYS08-0028

PHOTO

Description of morphotype:

Preserved as defoliated axis, with persistent pegs from needle attachment arranged helically on axis.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

MB005

Falkland Specimens:

RYS06-0807
RYS07-0878
RYS08-0028

Leaf Architecture - Dicots Only

LEAF				
Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS	
Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH			
# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Cunninghamia sp.	Morphotype #	FL090

Major Plant Group	CON	Organ Type	Leaf	Plant Family	Cupressaceae	Genus	*Cunninghamia*	Type spec. #	RYS06-0047

PHOTO

Description of morphotype:

Needles are apetiolate, and bases are attached broadly to the axis with a prominent mid vein. Needle apices are sharply tapered (acute) and needles are spirally arranged. Compare with Taiwania sp.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes RP=Republic MB=McAbee	
	RP236
	MB007
	MB017

Falkland Specimens:

RYS06-0047
RYS07-0277

Leaf Architecture - Dicots Only

LEAF			
Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS	
Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH			
# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Picea sp. seed	Morphotype #	FL091

Major Plant Group: CON | Organ Type: Seeds | Plant Family: Pinaceae | Genus: *Picea* | Type spec. #: RYS08-0030

PHOTO

Description of morphotype:

Wing is smaller and more rounded than Pinus seeds. Wing ~9 mm by ~6 mm at widest point, seed body 3 mm by ~2 mm, elliptic in shape.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP144
MB207

Falkland Specimens:

RYS06-0165, RYS06-0209, RYS06-0292, RYS06-1013, RYS06-1039, RYS07-0059, RYS07-0424, RYS07-0503, RYS07-0632, RYS07-0711, RYS07-0899, RYS08-0030

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Rosaceae sp. 1		Morphotype #	FL093
Major Plant Group: DIC	Organ Type: Leaf	Plant Family: Rosaceae	Genus:	Type spec. #	RYS08-0019

PHOTO

Description of morphotype:

Microphyll leaf with pinnate venation and irregular serrate teeth. Petiole is curved. Secondary venation is craspedodromous with decurrent attachment. Strong intersecondaries are present. Teeth are broadly acute and irregular in size and spacing.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☒
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0721
RYS07-0853
RYS08-0019

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 2	microphyll 3	Base Angle	acute	Apex Angle: obtuse
Laminar Shape	elliptic		Base Shape	convex	cuneate
Laminar Symmetry	symmetrical	L:W Ratio: 1.4-1.5:1	Apex Shape	convex	rounded
Base Symmetry	basal insertion asymmetrical		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	reticulating or ramifying
2° attachment	decurrent	Vein frequency	>1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	mixed
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	3	Teeth round	○ yes ◉ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cc/cv st/cv cv/cv st/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Acer sp. 3 (samara)	Morphotype #	FL095

Major Plant Group	DIC	Organ Type	Fruit	Plant Family	Sapindaceae	Genus	*Acer*	Type spec. #	RYS08-0031

PHOTO

Description of morphotype:

Acer samara. The attachment scar indicates that the strongly veined "back" of the wing is marginal (rather than medial in Deviacer). This morphotype has a more strongly veined back than FL066, and a more condensed pattern of venation, as well as a narrower wing. Distinct sulcus is present.

Distribution at Falkland site

Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP276?
MB308?

Falkland Specimens:

RYS07-0560, RYS07-0562, RYS07-0819, RYS07-0935, RYS07-0946, RYS07-0969, RYS07-0970, RYS08-0031

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Ginkgo dissecta	Morphotype #	FL096

Major Plant Group	GIN	Organ Type	Leaf	Plant Family	Ginkgoaceae	Genus	*Ginkgo*	Type spec. #	RYS08-0009

PHOTO

Description of morphotype:

Deeply lobed fan shaped leaf with open dichotomous venation. Laminar size is notophyll (~67 mm wide). Base shape is decurrent, apex is fan shaped and deeply notched with 4 main lobes, themselves shallowly notched. Primary venation is open-dichotomous with ~14 veins/cm. Distinguished from Ginkgo adiantoides by deeply divided lamina (sinus reaching almost to petiole) with multiple lobes.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP311
MB001

Falkland Specimens:

RYS08-0009

Leaf Architecture - Dicots Only

LEAF				
Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry	L:W Ratio		Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS			TEETH			
Areolation		# of Orders		Teeth Close	◌ yes ◌ no
F.E.V.s		Teeth/cm		Teeth round	◌ yes ◌ no
Marginal Ultimate Venation		Spacing		Teeth acute	◌ yes ◌ no
		Shape		Principal vein	
		Sinus		Termination	
		Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Bohlenia americana	Morphotype #	FL097

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Sapindaceae	*Bohlenia*	RYS07-0576

PHOTO

Description of morphotype:

Leaflet is large (mesophyll) and pinnately lobed, with pinnate primary venation and craspedodromous secondaries. Lamina is ovate and symmetrical, with asymmetrical basal width. Strong intersecondaries extend only a short distance from the midvein. Teeth are large and irregular in spacing with a simple apex.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP061

Falkland Specimens:

RYS07-0576

Leaf Architecture - Dicots Only

LEAF

Laminar Size	mesophyll		Petiolar Attach.	marginal
Clamp Size	mesophyll 2		Base Angle	obtuse; Apex Angle: acute
Laminar Shape	ovate		Base Shape	concave; concavo-convex
Laminar Symmetry	symmetrical	L:W Ratio 2.3:1	Apex Shape	
Base Symmetry	basal width asymmetrical		Margin Type	serrate; Lobation: pinnately

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	parallel to major secondaries
2° Vein Angle	one pair acute basal secondaries	Distal course	reticulating or ramifying
2° attachment	excurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	alternate percurrent	Epimedial3°	reticulate
3° Vein Course		Epimedial3° proximal course	not applicable
3° Angle to 1°	obtuse	Epimedial3° distal course	not applicable
3° Vein Angle Variability	inconsistent	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	1	Teeth round	○ yes ◉ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	fl/fl; fl/cv; cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	convex

Falkland (BC) Flora	Morphotype Name	Equisetum sp.	Morphotype #	FL098

Major Plant Group	SPE	Organ Type	Axis	Plant Family	Equisetaceae	Genus	*Equisetum*	Type spec. #	RYS07-0229

PHOTO

Description of morphotype:

Axis ~1 cm in width, with distinctive parallel grooves and ridges. Whorls of small leaves at nodes fused into a sheath at the base. Specimen RYS07-0933 preserves whorled leaves.

Distribution at Falkland site

Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP293
MB402

Falkland Specimens:

RYS06-0173
RYS07-0229
RYS07-0933

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL100

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-1040

PHOTO

Description of morphotype:

Microphyll to notophyll ovate leaf. Lamina is symmetrical and has a tendency towards being palmately lobed, but incisions not deep enough to form distinct lobes. Petiole often appears bent. Apex is acute and straight to convex in shape. Base is obtuse and rounded to shallowly cordate. Primary venation is basal actinodromous with simple agrophic veins present. Secondaries are semicraspedodromous with decurrent to deflected attachment. Intercostal tertiaries are alternate percurrent. Teeth are irregularly spaced, compound (two orders of teeth) and serrate with glandular apices. Possibly Acer sp.

Distribution at Falkland site		Similar Morphotypes (RP=Republic, MB=McAbee)
Unit 3	☒	RP012?
Unit 2	☒	
Unit 1	☒	
Scree	☒	

Falkland Specimens:

RYS06-0009, RYS06-0227, RYS06-1040, RYS07-0073, RYS07-0075, RYS07-0111, RYS07-0836, RYS07-0837, RYS07-0884, RYS07-0904, RYS07-0920, RYS07-0943, RYS07-0949, RYS08-0014

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal	
Clamp Size	microphyll 3	mesophyll 1	Base Angle	obtuse	Apex Angle: acute
Laminar Shape	ovate		Base Shape	cordate	convex
Laminar Symmetry	symmetrical	L:W Ratio 1.2:1	Apex Shape	convex	straight
Base Symmetry	symmetrical		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	absent
Agrophic Veins	simple	Minor 2° course	semicraspedodromous
# of Basal Veins	3	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	alternate percurrent	Epimedial3°	alternate percurrent
3° Vein Course		Epimedial3° proximal course	acute to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINER VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	2	Teeth Close	◯ yes ◉ no
Teeth/cm	3	Teeth Round	◉ yes ◯ no
Spacing	irregular	Teeth Acute	◉ yes ◯ no
Shape	cv/cv cc/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	convex

Falkland (BC) Flora | MORPHOTYPE NAME: Pinus sp. | MORPHOTYPE #: FL101

MAJOR PLANT GROUP: CON | ORGAN TYPE: Reproductive | PLANT FAMILY: Pinaceae | GENUS: *Pinus* | TYPE SPEC. #: RYS06-1028

PHOTO

Description of morphotype:

Pinus sp. ovulate cone. Large cone with cone scales and curved bracts visible. Bracts project about 5 mm from cone scale. Cone is 9+ cm long. Found in association with pine needles.

Distribution at Falkland site

- UNIT 3 ☐
- UNIT 2 ☐
- UNIT 1 ☐
- SCREE ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP280
MB204

Falkland Specimens:

RYS06-1028

Leaf Architecture - Dicots Only

LEAF: Laminar Size | Clamp Size | Laminar Shape | Laminar Symmetry | L:W Ratio | Base Symmetry | Petiolar Attach. | Base Angle | Apex Angle | Base Shape | Apex Shape | Margin Type | Lobation

1° to 2°: 1° Vein Category | Agrophic Veins | # of Basal Veins | 2° Vein Category | 2° Vein Spacing | 2° Vein Angle | 2° attachment | Interior secondaries | Minor 2° course | Inter-2° Veins | Length | Proximal course | Distal course | Vein frequency

3° to 5°: 3° Vein Category | 3° Vein Course | 3° Angle to 1° | 3° Vein Angle Variability | Exterior tertiary course | Epimedial3° | Epimedial3° proximal course | Epimedial3° distal course | 4° Vein Category | 5° Vein Category

FINE VEINS: Areolation | F.E.V.s | Marginal Ultimate Venation

TEETH: # of Orders | Teeth/cm | Spacing | Shape | Sinus | Apex | Teeth Close ◌ yes ◌ no | Teeth round ◌ yes ◌ no | Teeth acute ◌ yes ◌ no | Principal vein | Termination | Accesory vein

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL102
Major Plant Group: DIC	Organ Type: Leaf	Plant Family:	Genus:	Type spec. #: RYS06-1029

PHOTO

Description of morphotype:

Microphyll leaf with cordate base and entire margin. Base is symmetrical and cordate. Apex is not preserved. Lamina is unlobed and membranaceous in texture. Margin is entire. Primary venation is basal actinodromous with simple agrophic veins. Termination of secondary veins indistinct. Intercostal tertiary veins are opposite percurrent. Quaternary veins are alternate percurrent.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-1029

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	Base Angle	obtuse
Laminar Shape	ovate	Apex Angle	not visible
Laminar Symmetry	not visible	Base Shape	cordate
L:W Ratio		Apex Shape	not visible
Base Symmetry	symmetrical	Margin Type	entire
		Lobation	unlobed

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	absent
Agrophic Veins	simple	Minor 2° course	semicraspedodromous
# of Basal Veins	7	Inter-2° Veins	absent
2° Vein Category	not visible	Length	not applicable
2° Vein Spacing	not visible	Proximal course	not applicable
2° Vein Angle	not visible	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	sinuous; straight	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing exmedially	4° Vein Category	alternate percurrent
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

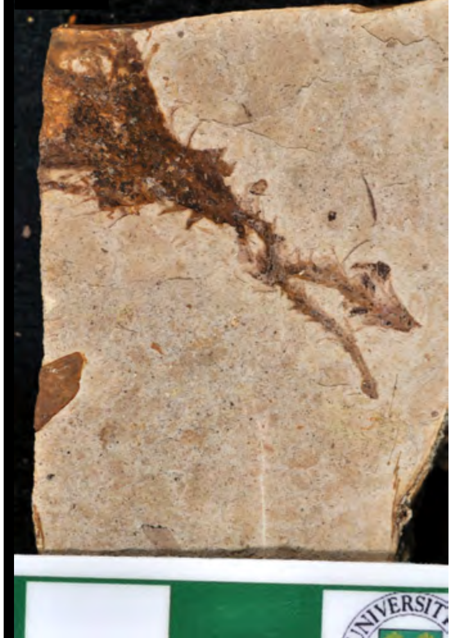
Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Bryophyte?	Morphotype #	FL103
Major Plant Group: BRY	Organ Type: Axis	Plant Family:	Genus:	Type spec. #: RYS07-0793

PHOTO



Description of morphotype:

Small, delicate leaves visible on axis which appears to have roots. Entire specimen about 3.5 cm in length. Individual leaves ~2 mm long.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP297

Falkland Specimens:

RYS07-0793

Leaf Architecture - Dicots Only

LEAF			
Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS	
Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH			
# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora | Morphotype Name: Koelreuteria arnoldi | Morphotype #: FL104

Major Plant Group: DIC | Organ Type: Fruit | Plant Family: Sapindaceae | Genus: *Koelreuteria* | Type spec. #: RYS08-0035

PHOTO

Description of morphotype:

Oval to heart shaped winged fruit, entire margined, with veins radiating out from central axis. One end is tapered, and the other notched. 20 mm long by 14 mm wide. Sinus is 5 mm. In the top half of the fruit, the veins branch about midway to the margin. In the bottom half, the veins form an irregular reticulate net.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP103
MB311

Falkland Specimens:

RYS08-0035

Leaf Architecture - Dicots Only

LEAF

Laminar Size | Clamp Size | Laminar Shape | Laminar Symmetry | L:W Ratio | Base Symmetry

Petiolar Attach. | Base Angle | Apex Angle | Base Shape | Apex Shape | Margin Type | Lobation

1° to 2°

1° Vein Category | Agrophic Veins | # of Basal Veins | 2° Vein Category | 2° Vein Spacing | 2° Vein Angle | 2° attachment

Interior secondaries | Minor 2° course | Inter-2° Veins | Length | Proximal course | Distal course | Vein frequency

3° to 5°

3° Vein Category | 3° Vein Course | 3° Angle to 1° | 3° Vein Angle Variability | Exterior tertiary course

Epimedial3° | Epimedial3° proximal course | Epimedial3° distal course | 4° Vein Category | 5° Vein Category

FINE VEINS

Areolation | F.E.V.s | Marginal Ultimate Venation

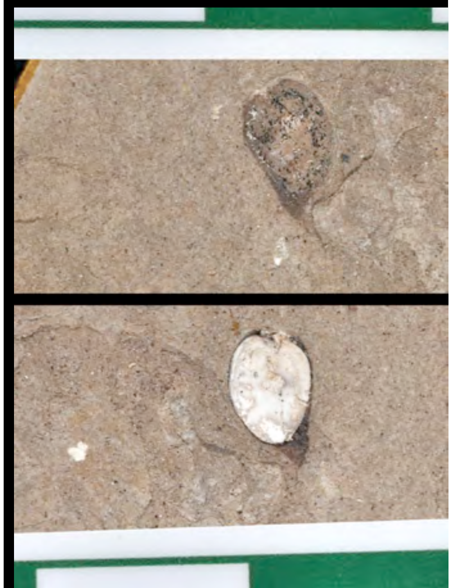
TEETH

# of Orders | Teeth/cm | Spacing | Shape | Sinus | Apex

Teeth Close ◌ yes ◌ no | Teeth round ◌ yes ◌ no | Teeth acute ◌ yes ◌ no | Principal vein | Termination | Accesory vein

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL105
Major Plant Group		Organ Type: Fruit	Plant Family	
Genus		Type spec. #	RYS08-0037	

PHOTO



Description of morphotype:

Small oval fruit, one part displaying an unusual preservation (cast?). Fruit is 7 mm long and 4 mm wide with slightly cordate base and tapering end. Possibly the nutlet of an Acer sp. samara with missing wing.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS08-0037

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

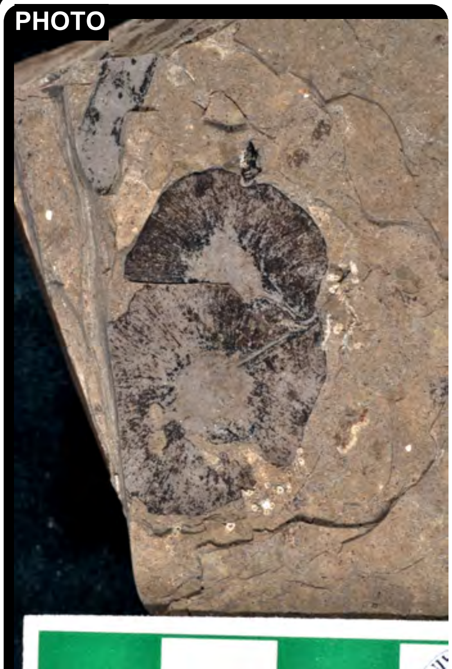
TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Dipteronia brownii	Morphotype #	FL108

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Fruit	Sapindaceae	*Dipteronia*	RYS07-0807

PHOTO



Description of morphotype:

Winged fruit in pairs (possibly three, but third not visible). There is a central seed (appears empty in this specimen) surrounded by orbicular wing with veins running from centre to margin in opposite percurrent pattern with some branching. Vascularized stalk extending to seed visible. Each individual fruit is 1.1 cm (RYS06-1030) to 1.7 cm (RYS07-0807) in diameter.

Distribution at Falkland site

Unit	
Unit 3	☐
Unit 2	☐
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP073
MB306

Falkland Specimens:

RYS06-1030
RYS07-0807

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		Base Shape	
L:W Ratio		Apex Shape	
Base Symmetry		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL109

Major Plant Group	DIC	Organ Type	Fruit	Plant Family		Genus		Type spec. #	RYS06-1031

PHOTO

Description of morphotype:

Round fruit (possibly an endocarp?) 9 mm x 10 mm, slightly tapered at one end. Main veins run longitudinally, with freely ramifying veins or ridges between, giving an open, reticulate appearance. Possibly Rosaceae (Prunus) or Icacinceae (Icacinicarya) endocarp.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-1031

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL110

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf			RYS08-0053

PHOTO

Description of morphotype:

Microphyll to notophyll elliptic leaf with irregular, compound, crenate teeth. Lamina is symmetrical. Base is obtuse and convex. Apex is not preserved. Primary venation is pinnate. Secondary venation is craspedodromous. Attachment is decurrent in proximal half of lamina, becoming excurrent distally. Agrophic veins and intersecondary veins absent. Intercostal tertiaries are opposite percurrent. Teeth are irregularly spaced and compound, crenate to serrate with simple apices.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0095
RYS07-0343
RYS08-0053

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	mesophyll 1	Base Angle	obtuse
			Apex Angle	not visible
Laminar Shape	elliptic		Base Shape	convex
Laminar Symmetry	symmetrical	L:W Ratio 1.3:1	Apex Shape	not visible
Base Symmetry	symmetrical		Margin Type	crenate, serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	proximal secondaries decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	sinuous, convex	Epimedial3° proximal course	parallel to intercostal tertiaries
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	irregular reticulate
Exterior tertiary course	not visible	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2	Teeth Close	◉ yes ○ no
Teeth/cm	3	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cv/cv, fl/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Incertae sedis					Morphotype #	FL111
Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus	
Type spec. #	RYS08-0055						

PHOTO

Description of morphotype:

Microphyll elliptic leaf with crenate teeth. Lamina is symmetrical. Apex is obtuse and convex with a slightly retuse apex. Base is obtuse and rounded (possibly slightly cordate). Primary venation is pinnate. Secondary venation is craspedodromous. Sparse intersecondary veins are present. Intercostal tertiaries are opposite percurrent. Higher order venation indistinct. Teeth are compound and crenate with glandular apices. Possibly “Acer” arcticum.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS08-0055

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	Base Angle	obtuse
Laminar Shape	elliptic	Apex Angle	obtuse
Laminar Symmetry	symmetrical	Base Shape	rounded
L:W Ratio	1.1:1	Apex Shape	convex; retuse
Base Symmetry	symmetrical	Margin Type	crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior Secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	decreasing toward base	Proximal course	perpendicular to midvein
2° Vein Angle	abruptly increasing towards base	Distal course	not visible
2° attachment	excurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	not visible
3° Vein Course	convex	Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse	Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible	4° Vein Category	not visible
Exterior tertiary course	terminating at margin	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders	2	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	○ yes ◉ no
Shape	cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	running from sinus

Falkland (BC) Flora	Morphotype Name	Chamaecyparis sp.	Morphotype #	FL113

Major Plant Group	CON	Organ Type	Reproductive	Plant Family	Cupressaceae	Genus	*Chamaecyparis*	Type spec. #	RYS06-1034

PHOTO

Description of morphotype:

Woody ovulate cone, ellipsoid in shape. Cone is ~8 mm long by 5 mm wide. Preservation is not good, but cone scales appear to be attached in pairs to a slender axis, with at least 8 cone scales present.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☐
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP282
MB214

Falkland Specimens:

RYS06-1034

Leaf Architecture - Dicots Only

LEAF			
Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS		TEETH			
Areolation		# of Orders		Teeth Close	◌ yes ◌ no
F.E.V.s		Teeth/cm		Teeth round	◌ yes ◌ no
Marginal Ultimate Venation		Spacing		Teeth acute	◌ yes ◌ no
		Shape		Principal vein	
		Sinus		Termination	
		Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Photinia pageae	Morphotype #	FL114

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Rosaceae	Genus	*Photinia*	Type spec. #	RYS07-0251

PHOTO

Description of morphotype:

Laminar size microphyll to notophyll but predominantly notophyll. Petiole is long and curved. Leaf is narrow and symmetrical, with occasionally asymmetrical base. Primary venation is pinnate and secondary venation is semi-craspedodromous. Strong intersecondary veins are present. Teeth are sharply serrate and glandular in apical portion of blade. Basal portion of lamina has fewer teeth (to almost entire near base).

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes RP=Republic MB=McAbee	RP044 MB046?

Falkland Specimens:

RYS06-0097, RYS06-0332, RYS06-0466, RYS06-0722, RYS06-0911, RYS06-0968, RYS07-0139, RYS07-0170, RYS07-0251, RYS07-0296, RYS07-0350, RYS07-0509, RYS07-0630, RYS07-0649, RYS07-0715, RYS07-0742, RYS07-0778, RYS07-0798, RYS07-0881, RYS08-0050

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	mesophyll 1	Base Angle	acute
			Apex Angle	acute
Laminar Shape	ovate	elliptic	Base Shape	convex
Laminar Symmetry	symmetrical	L:W Ratio 2.6-2.7:1	Apex Shape	straight / convex
Base Symmetry	symmetrical		Margin Type	serrate
			Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	uniform	Proximal course	parallel to major secondaries
2° Vein Angle	smoothly increasing towards base	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	ramified
3° Vein Course	exmedially ramified	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	dichotomizing (fevs)
Exterior tertiary course	not visible	5° Vein Category	

FINE VEINS

Areolation	poorly developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth round	○ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	st/cv, cc/cv, cc/fl, fl/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	cf. Itea sp.	Morphotype #	FL115

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Iteaceae	Genus	*cf. Itea*	Type spec. #	RYS07-0199

PHOTO

Description of morphotype:

Mesophyll leaf with very minutely and shallowly serrate margin. Secondaries are eucamptodromous, upturned and gradually diminishing inside the margin. Apex not preserved in type specimen. Same as RP019 (cf. Itea, currently under review).

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes
RP=Republic
MB=McAbee

RP019

Falkland Specimens:

RYS07-0051
RYS07-0199
RYS07-0571
RYS07-0572

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	mesophyll	Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 2	Base Angle	obtuse	Apex Angle	not visible
Laminar Shape	elliptic	ovate	Base Shape	convex	cordate	
Laminar Symmetry	symmetrical	L:W Ratio	Apex Shape	not visible		
Base Symmetry	symmetrical		Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	eucamptodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial3°	mixed
3° Vein Course	sinuous	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	perpendicular	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	irregular reticulate
Exterior tertiary course	terminating at margin	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	7	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	st/fl cc/fl	Principal vein	present
Sinus	angular	Termination	marginal
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Incertae sedis			Morphotype #	FL116
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	
Genus		Type spec. #	RYS07-0140		

PHOTO

Description of morphotype:

Microphyll elliptic to obovate leaf with emarginate apex. Lamina is symmetrical with bent petiole. Apex is obtuse and emarginate. Base is acute and convex to straight. Primary venation is pinnate. Secondary venation is craspedodromous with veins smoothly arching towards the apex. Intercostal tertiaries are opposite percurrent. Teeth are simple and shallowly serrate with glandular apices, appearing almost as bumps on the margin.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0140
RYS07-0929

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		
Clamp Size	microphyll 2		
Laminar Shape	obovate	elliptic	
Laminar Symmetry	symmetrical	L:W Ratio	1.1-1.5:1
Base Symmetry	symmetrical		

Petiolar Attach.	marginal		
Base Angle	acute	Apex Angle	obtuse
Base Shape	convex	cuneate	
Apex Shape	emarginate	convex	
Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate
Agrophic Veins	none
# of Basal Veins	1
2° Vein Category	craspedodromous
2° Vein Spacing	not visible
2° Vein Angle	smoothly decreasing towards base
2° attachment	decurrent

Interior secondaries	absent
Minor 2° course	not applicable
Inter-2° Veins	absent
Length	not applicable
Proximal course	not applicable
Distal course	not applicable
Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	
3° Vein Course	straight	convex
3° Angle to 1°	obtuse	
3° Vein Angle Variability	increasing basally	
Exterior tertiary course	terminating at margin	

Epimedial3°	opposite percurrent
Epimedial3° proximal course	parallel to intercostal tertiaries
Epimedial3° distal course	parallel to intercostal tertiaries
4° Vein Category	alternate percurrent
5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1		
Teeth/cm	4		
Spacing	irregular		
Shape	st/cv	cv/cv	cv/cc
Sinus	angular		
Apex	non-specific glandular		

Teeth Close	○ yes ◉ no
Teeth round	○ yes ◉ no
Teeth acute	◉ yes ○ no
Principal vein	not visible
Termination	not visible
Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Alnus sp. 2	Morphotype #	FL117		
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Betulaceae
Genus	*Alnus*	Type spec. #	RYS07-0244		

PHOTO

Description of morphotype:

Microphyll to notophyll elliptic leaf with asymmetrical base. Base is obtuse and convex to cordate. Apex is acute and convex. Margin is unlobed and crenate to serrate. Primate venation is pinnate. Secondary venation is craspedodromous with angle of attachment smoothly increasing apically. Agrophic veins and intersecondary veins absent. Intercostal tertiaries are opposite percurrent, mostly simple but occasionally branched. Areolation is well developed. Teeth are compound, irregularly spaced, with glandular apices. Compare to FL020 and FL159.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes (RP=Republic, MB=McAbee)
MB074

Falkland Specimens:

RYS07-0244
RYS07-0657
RYS08-0058

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	
Clamp Size	microphyll 3	mesophyll 1	
Laminar Shape	elliptic		
Laminar Symmetry	symmetrical	L:W Ratio	1.7:1
Base Symmetry	basal insertion asymmetrical		
Petiolar Attach.	marginal		
Base Angle	obtuse	Apex Angle	acute
Base Shape	convex	cordate	
Apex Shape	convex		
Margin Type	crenate	serrate	
Lobation	unlobed		

1° to 2°

1° Vein Category	pinnate
Agrophic Veins	none
# of Basal Veins	1
2° Vein Category	craspedodromous
2° Vein Spacing	decreasing toward base
2° Vein Angle	smoothly increasing towards base
2° attachment	excurrent
Interior secondaries	absent
Minor 2° course	not applicable
Inter-2° Veins	absent
Length	not applicable
Proximal course	not applicable
Distal course	not applicable
Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent
3° Vein Course	convex
3° Angle to 1°	obtuse
3° Vein Angle Variability	decreasing exmedially
Exterior tertiary course	terminating at margin
Epimedial3°	opposite percurrent
Epimedial3° proximal course	perpendicular to midvein
Epimedial3° distal course	parallel to intercostal tertiaries
4° Vein Category	alternate percurrent
5° Vein Category	irregular reticulate

FINE VEINS

Areolation	well developed
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders	2
Teeth/cm	4
Spacing	irregular
Shape	cv/cv
Sinus	angular
Apex	non-specific glandular
Teeth Close	◉ yes ○ no
Teeth Round	◉ yes ○ no
Teeth Acute	◉ yes ○ no
Principal vein	present
Termination	proximal flank of tooth
Accesory vein	running from sinus

Falkland (BC) Flora	Morphotype Name	Incertae sedis		Morphotype #	FL118
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	
Genus		Type spec. #	RYS07-0062		

PHOTO

Description of morphotype:

Microphyll elliptic leaf with entire margin. Petiole is stout and midrib is stout at the base of the leaf, diminishing apically. Lamina is symmetrical to slightly asymmetrical; base is symmetrical to basal insertion asymmetrical. Apex angle is acute and straight to convex in shape. Base angle is acute and shape is convex to decurrent on one side. Primary venation is pinnate. Secondary venation is poorly preserved but appears eucamptodromous (losing gauge by attenuation or branching). Spacing and angle of attachment is inconsistent. Intersecondary veins are present. Higher order venation indistinct. Margin is entire and slightly undulating.

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee	
Unit 3	☒	MB069?	
Unit 2	☐		
Unit 1	☒		
Scree	☐		

Falkland Specimens:

RYS06-0564
RYS07-0062
RYS07-0161

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 3		Base Angle	acute	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	convex	decurrent
Laminar Symmetry	symmetrical	L:W Ratio: 2.7:1	Apex Shape	convex	straight
Base Symmetry	symmetrical to basal insertion asymmetrical		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	eucamptodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	inconsistent	Distal course	reticulating or ramifying
2° attachment	excurrent	Vein frequency	>1 per intercostal area

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

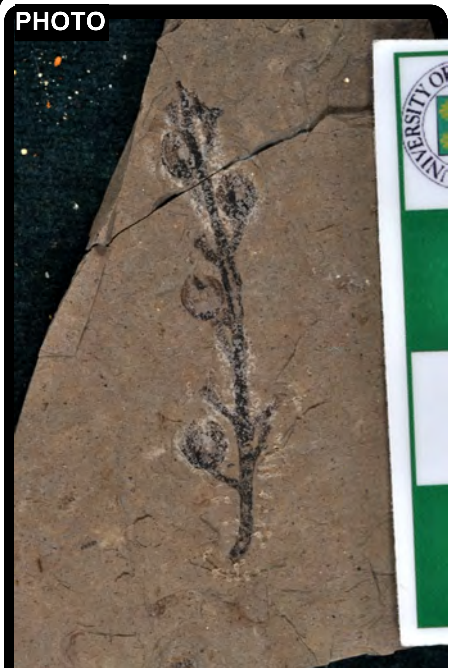
TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth Round	◌ yes ◌ no
Spacing		Teeth Acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL120

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family		Genus		Type spec. #	RYS07-0818

PHOTO



Description of morphotype:

Infructescence with a central axis about 4 cm long. Fruits born singly on short pedicels about 3 mm long arranged alternately to sub-oppositely. Each fruit rounded to ovoid. May be capsules with valves split longitudinally.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☐
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP307?
RP308?

Falkland Specimens:

RYS07-0818

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL121

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family		Genus		Type spec. #	RYS07-0828

PHOTO

Description of morphotype:

Small flower, 0.6 cm across, with five petals and large central disc (possibly a floral nectary). Remnants of narrow sepals (or bracts) visible alternating with petals.

Distribution at Falkland site		Similar Morphotypes RP=Republic MB=McAbee
Unit 3	☐	RP314
Unit 2	☒	
Unit 1	☐	
Scree	☐	

Falkland Specimens:

RYS07-0828

Leaf Architecture - Dicots Only

LEAF				
Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle		Apex Angle	
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type		Lobation	

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS		TEETH			
Areolation		# of Orders		Teeth Close	○ yes ○ no
F.E.V.s		Teeth/cm		Teeth round	○ yes ○ no
Marginal Ultimate Venation		Spacing		Teeth acute	○ yes ○ no
		Shape		Principal vein	
		Sinus		Termination	
		Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	*Zizyphoides* sp.	Morphotype #	FL122

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Trochodendraceae	*Zizyphoides*	RYS06-0697

PHOTO

Description of morphotype:

Elliptic to broadly ovate leaf, microphyll to notophyll in size. Leaf is unlobed with a crenate margin characterized by large, irregular, glandular teeth. Apex angle obtuse; apex shape convex. Primary venation suprabasal actinodromous with 5-7 basal veins and compound agrophic veins. Major secondaries festooned semicraspedodromous, with irregular spacing and decurrent attachment. Tooth spacing is irregular, with one to occasionally two orders of teeth. About 4 teeth per cm (but variable); sinus shape rounded or acute. Principal vein is present and terminates at apex of tooth which is glandular or simple.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP037
MB049

Falkland Specimens:

RYS06-0697
RYS07-0580
RYS07-0894

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal	
Clamp Size	microphyll 3		Base Angle	obtuse	Apex Angle: obtuse
Laminar Shape	elliptic	ovate	Base Shape	rounded	convex
Laminar Symmetry	symmetrical	L:W Ratio: 1.1-1.2:1	Apex Shape	convex	
Base Symmetry	symmetrical		Margin Type	crenate	Lobation: unlobed

1° to 2°

1° Vein Category	suprabasal actinodromous	Interior secondaries	present
Agrophic Veins	compound	Minor 2° course	semicraspedodromous
# of Basal Veins	7	Inter-2° Veins	present
2° Vein Category	festooned semicraspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	perpendicular to midvein
2° Vein Angle	uniform	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	>1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	reticulate
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	2-4	Teeth Round	◉ yes ○ no
Spacing	irregular	Teeth Acute	○ yes ◉ no
Shape	cv/cv st/cv cc/cv	Principal vein	present
Sinus	rounded-angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	straight or concave

Falkland (BC) Flora

Morphotype Name	cf. Musophyllum complicatum	Morphotype #	FL123
Major Plant Group	MON	Organ Type	Leaf
Plant Family		Genus	
Type spec. #	RYS06-0113		

PHOTO

Description of morphotype:

Monocot leaf with parallel venation, major veins fairly widely spaced (1-2 mm apart). Foliage is fragmented with overlapping segments. RYS07-0493 may be dissected.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0113
RYS07-0493

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Betulaceae sp. 2	Morphotype #	FL124

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family	Betulaceae	Genus		Type spec. #	RYS07-0346

PHOTO

Description of morphotype:

Staminate inflorescence. Pendulous catkin ~0.5 mm wide, 3+ cm long, appears to be less woody or robust than FL006. Type specimen shows two catkins in attachment from peduncle.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes (RP=Republic, MB=McAbee)
RP102?
MB317

Falkland Specimens:

RYS06-0048, RYS06-0146, RYS06-0149, RYS06-0154, RYS06-0385, RYS06-0419, RYS06-0873, RYS06-0898, RYS06-0899, RYS06-0930, RYS06-1038, RYS07-0346, RYS07-0477, RYS07-0859, RYS07-0918, RYS07-0972

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL126

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0279

PHOTO

Description of morphotype:

Notophyll elliptic (oblate) leaf with entire margin. Lamina is symmetrical and unlobed. Apex angle is obtuse and emarginate (to rounded and retuse). Base is not visible. Primary venation is actinodromous with agrophic veins present. Secondary venation is brochidodromous. Interior secondaries and intersecondary veins are present. Intercostal tertiary veins are opposite percurrent. Exterior tertiaries and marginal ultimate venation are looped.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes RP=Republic MB=McAbee	RP158?

Falkland Specimens:

RYS07-0279
RYS07-0939

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	not visible	
Clamp Size	mesophyll 1		Base Angle	not visible	Apex Angle: obtuse
Laminar Shape	elliptic		Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio 0.9:1	Apex Shape	retuse	emarginate
Base Symmetry	not visible		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	actinodromous	Interior secondaries	present
Agrophic Veins	simple	Minor 2° course	simple brochidodromous
# of Basal Veins	not visible	Inter-2° Veins	present
2° Vein Category	brochidodromous	Length	<50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	not visible
2° attachment	excurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	not visible
3° Vein Course	straight	convex	Epimedial3° proximal course	
3° Angle to 1°	obtuse		Epimedial3° distal course	
3° Vein Angle Variability	increasing exmedially		4° Vein Category	not visible
Exterior tertiary course	looped		5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	looped

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	*Rhus malloryi*	Morphotype #	FL127
Major Plant Group	DIC	Organ Type	Leaf
Plant Family	Anacardiaceae	Genus	*Rhus*
Type spec. #	RYS07-0158		

PHOTO

Description of morphotype:

Microphyll leaf, narrowly ovate to elliptic. Primary venation is pinnate with no agrophic veins. Major secondaries craspedodromous. Secondaries occasionally branch near the margin, sending an exmedial branch to the adjacent sinus. Intersecondaries present with variable length and angle of attachment. Teeth are large and regular, with long proximal flanks.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP043

Falkland Specimens:

RYS07-0158

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	not visible
Clamp Size	microphyll 3	Base Angle	obtuse
Laminar Shape	ovate	Apex Angle	not visible
Laminar Symmetry	symmetrical	Base Shape	convex
L:W Ratio	2.4:1	Apex Shape	not visible
Base Symmetry	not visible	Margin Type	serrate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	inconsistent	Distal course	perpendicular to subjacent secondary
2° attachment	excurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	mixed opp/alt	Epimedial3°	not visible
3° Vein Course	sinuous	Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse	Epimedial3° distal course	not visible
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	irregular reticulate
Exterior tertiary course	terminating at margin	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	1 to 2	Teeth round	○ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	fl/fl fl/cv cc/fl cc/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	straight or concave

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL128

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0841

PHOTO

Description of morphotype:

Microphyll entire-margined leaf. Lamina is symmetrical and lobed, either bilobed or palmatisect (although the appears of the lobes may be due to damage). The apex of the lobes are obtuse and convex to rounded in shape. The base angle is obtuse and decurrent. Primary venation is basal actinodromous. Secondary veins are cladodromous (freely ramifying exmedially). Intercostal tertiaries are irregular reticulate and exmedially ramified. Higher order venation indistinct. It is possible that this is a pathogenic leaf. Note that CLAMP laminar size refers to lobe size. Possibly a damaged Sassafras sp. leaf.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0841

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 2		Base Angle	obtuse	Apex Angle: acute
Laminar Shape	obovate		Base Shape	decurrent	
Laminar Symmetry	symmetrical	L:W Ratio 1:1	Apex Shape	convex	rounded
Base Symmetry	symmetrical		Margin Type	entire	Lobation: bilobed, palmately

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	3?	Inter-2° Veins	absent
2° Vein Category	cladodromous	Length	not applicable
2° Vein Spacing	irregular	Proximal course	not applicable
2° Vein Angle	inconsistent	Distal course	not applicable
2° attachment	deflected	Vein frequency	not applicable

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	not visible
3° Vein Course	exmedially ramified	Epimedial3° proximal course	
3° Angle to 1°	not applicable	Epimedial3° distal course	
3° Vein Angle Variability	inconsistent	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FV EINS / VEINS

Areolation	poorly developed
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth Round	◌ yes ◌ no
Spacing		Teeth Acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL129
Major Plant Group: DIC	Organ Type: Reproductive	Plant Family:	Genus:	Type spec. #: RYS06-1036

PHOTO

Description of morphotype:

Appears to be a single detached petal, 10 mm long by 7 mm wide. Petal is broadly elliptic with reticulate venation.

Distribution at Falkland site

- [ ] Unit 3
- [x] Unit 2
- [ ] Unit 1
- [ ] Scree

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-1036

Leaf Architecture - Dicots Only

LEAF

Laminar Size
Clamp Size
Laminar Shape
Laminar Symmetry
L:W Ratio
Base Symmetry
Petiolar Attach.
Base Angle
Apex Angle
Base Shape
Apex Shape
Margin Type
Lobation

1° to 2°

1° Vein Category
Agrophic Veins
# of Basal Veins
2° Vein Category
2° Vein Spacing
2° Vein Angle
2° attachment
Interior secondaries
Minor 2° course
Inter-2° Veins
Length
Proximal course
Distal course
Vein frequency

3° to 5°

3° Vein Category
3° Vein Course
3° Angle to 1°
3° Vein Angle Variability
Exterior tertiary course
Epimedial3°
Epimedial3° proximal course
Epimedial3° distal course
4° Vein Category
5° Vein Category

FV INE NIR ENS

Areolation
F.E.V.s
Marginal Ultimate Venation

TEETH

# of Orders
Teeth/cm
Spacing
Shape
Sinus
Apex
Teeth Close ○ yes ○ no
Teeth round ○ yes ○ no
Teeth acute ○ yes ○ no
Principal vein
Termination
Accesory vein

Falkland (BC) Flora	Morphotype Name	Monocot sp. 2	Morphotype #	FL130

Major Plant Group	MON	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0851

PHOTO

Description of morphotype:

Leaf type is similar to FL005 (generalized monocot foliage), except that it has a prominent raised midrib. The other venation is indistinct but appears to be parallelodromous. Leaf is chartaceous in texture, 8+ cm long, and 2.6 cm wide. Midrib is 3 mm wide.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0851

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	
			Apex Angle	
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	
			Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	?Adiantum sp. 1	Morphotype #	FL131

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
PTE	Leaf	Pteridaceae	*?Adiantum*	RYS07-0852

PHOTO

Description of morphotype:

Small fern pinna. Portion preserved is ~2 cm long, 1.4 cm wide. Pinnules are alternately attached, each one leptophyll to nanophyll in size (largest ~7 mm by 5 mm). Leaf venation is open dichotomous. There is a dominant midvein, but it also dichotomizes. Veins terminate at the margin which is crenate to serrate.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☐
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP291
MB401?

Falkland Specimens:

RYS07-0852

Leaf Architecture - Dicots Only

LEAF				
Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS	
Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH			
# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Rosaceae sp. 2	Morphotype #	FL132

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Rosaceae	Genus		Type spec. #	RYS07-0854

PHOTO

Description of morphotype:

Narrow ovate to oblong leaf with large teeth. Teeth are broadly serrate, some with small, sharp secondary teeth on proximal flank. Primary venation is pinnate and secondary venation is craspedodromous. Intersecondary veins are present. Tertiaries are reticulate to ramified.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP042?

Falkland Specimens:

RYS07-0854
RYS07-0855

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 1	Base Angle	obtuse	Apex Angle	acute
Laminar Shape	ovate	oblong	Base Shape	not visible		
Laminar Symmetry	symmetrical	L:W Ratio 3.1:1	Apex Shape	not visible		
Base Symmetry	symmetrical		Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	uniform	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	not visible
2° attachment	decurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	ramified
3° Vein Course	exmedially ramified	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	dichotomizing (fevs)
Exterior tertiary course	terminating at margin	5° Vein Category	not applicable

FINE VEINS

Areolation	poorly developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders	2	Teeth Close	◉ yes ○ no
Teeth/cm	2	Teeth round	○ yes ◉ no
Spacing	regular	Teeth acute	◉ yes ○ no
Shape	cc/cv cv/cv st/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	simple	Accesory vein	looped

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL134

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0305

PHOTO

Description of morphotype:

Microphyll ovate leaf with distinct secondary veins (branching before reaching the margin). Lamina is unlobed and symmetrical with basal extension slightly asymmetrical. Texture is membranaceous. Apex is obtuse and rounded. Base is obtuse and cordate. Primary venation is pinnate. Secondary veins are cladodromous (branching before reaching the margin). Intercostal tertiaries are opposite percurrent. Margin is indistinct due to preservation.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0305

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 3		Base Angle	obtuse	Apex Angle: obtuse
Laminar Shape	ovate		Base Shape	cordate	
Laminar Symmetry	symmetrical	L:W Ratio 0.9:1	Apex Shape	rounded	convex
Base Symmetry	basal extension asymmetrical		Margin Type	?	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	5	Inter-2° Veins	absent
2° Vein Category	cladodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	opposite percurrent
3° Vein Course	straight	sinuous	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	not visible
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	not visible
Exterior tertiary course	not visible		5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Abies milleri			Morphotype #	FL136
Major Plant Group	CON	Organ Type	Seeds	Plant Family	Pinaceae
Genus	*Abies*	Type spec. #	RYS07-0875		

PHOTO

Description of morphotype:

Abies winged seed. Wing is large and wedge shaped. 1.5 cm long, 1.4 cm wide at distal end and 0.9 cm at proximal end. Seed body is large, 1.3 cm x 0.5 cm.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP114
MB202

Falkland Specimens:

RYS07-0875

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL137

Major Plant Group		Organ Type	Reproductive	Plant Family		Genus		Type spec. #	RYS06-0605

PHOTO

Description of morphotype:

Small samara. Seed body is 3 mm x 2 mm, oval (elliptic) in shape, surrounded by tissue (cup?). Wing is small, 5 mm x 3 mm, broadest just below attachment to seed body, with an angular deflection (about 30 degrees from long axis of seed body). Possibly Picea sp. seed.

Distribution at Falkland site

- ☐ Unit 3
- ☐ Unit 2
- ☒ Unit 1
- ☐ Scree

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0605

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora | Morphotype Name: Pseudolarix sp. | Morphotype #: FL138

Major Plant Group: CON | Organ Type: Seeds | Plant Family: Pinaceae | Genus: *Pseudolarix* | Type spec. #: RYS07-0957

PHOTO

Description of morphotype:

Pseudolarix winged seed. Seed body is 7 mm x 4 mm. Wing extends 18 mm beyond seed, and is widest at base (just below point of attachment with seed) ~7 mm, then narrowing to distal end, fairly straight on admedial side.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP143
MB209

Falkland Specimens:

RYS06-0026, RYS06-0737, RYS06-0812, RYS07-0097, RYS07-0240, RYS07-0312, RYS07-0784, RYS07-0885, RYS07-0928, RYS07-0957

Leaf Architecture - Dicots Only

LEAF

Laminar Size | Clamp Size | Laminar Shape | Laminar Symmetry | L:W Ratio | Base Symmetry

Petiolar Attach. | Base Angle | Apex Angle | Base Shape | Apex Shape | Margin Type | Lobation

1° to 2°

1° Vein Category | Agrophic Veins | # of Basal Veins | 2° Vein Category | 2° Vein Spacing | 2° Vein Angle | 2° attachment

Interior secondaries | Minor 2° course | Inter-2° Veins | Length | Proximal course | Distal course | Vein frequency

3° to 5°

3° Vein Category | 3° Vein Course | 3° Angle to 1° | 3° Vein Angle Variability | Exterior tertiary course

Epimedial3° | Epimedial3° proximal course | Epimedial3° distal course | 4° Vein Category | 5° Vein Category

FINE VEINS

Areolation | F.E.V.s | Marginal Ultimate Venation

TEETH

# of Orders | Teeth/cm | Spacing | Shape | Sinus | Apex

Teeth Close ◯ yes ◯ no | Teeth round ◯ yes ◯ no | Teeth acute ◯ yes ◯ no | Principal vein | Termination | Accesory vein

Falkland (BC) Flora	Morphotype Name	Metasequoia occidentalis		Morphotype #	FL139
Major Plant Group	CON	Organ Type	Reproductive	Plant Family	Cupressaceae
Genus	*Metasequoia*	Type spec. #	RYS06-0374		

PHOTO

Description of morphotype:

Fertile shoot with pollen cones. Individual cones are round and attached oppositely with subtending bracts.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP285
MB203

Falkland Specimens:

RYS06-0374
RYS07-0880

Leaf Architecture - Dicots Only

LEAF: Laminar Size; Clamp Size; Laminar Shape; Laminar Symmetry; L:W Ratio; Base Symmetry; Petiolar Attach.; Base Angle; Apex Angle; Base Shape; Apex Shape; Margin Type; Lobation

1° to 2°: 1° Vein Category; Agrophic Veins; # of Basal Veins; 2° Vein Category; 2° Vein Spacing; 2° Vein Angle; 2° attachment; Interior secondaries; Minor 2° course; Inter-2° Veins; Length; Proximal course; Distal course; Vein frequency

3° to 5°: 3° Vein Category; 3° Vein Course; 3° Angle to 1°; 3° Vein Angle Variability; Exterior tertiary course; Epimedial3°; Epimedial3° proximal course; Epimedial3° distal course; 4° Vein Category; 5° Vein Category

FINE VEINS: Areolation; F.E.V.s; Marginal Ultimate Venation

TEETH: # of Orders; Teeth/cm; Spacing; Shape; Sinus; Apex; Teeth Close ◌ yes ◌ no; Teeth round ◌ yes ◌ no; Teeth acute ◌ yes ◌ no; Principal vein; Termination; Accesory vein

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL140

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0887

PHOTO

Description of morphotype:

Mesophyll elliptic leaf with tendency towards being palmately lobed (but incisions not deep enough to be considered true lobes). Apex is acute and convex. Base is not visible. Primary venation is pinnate (or possibly actinodromous - basal portion of veins not visible). Simple agrophic veins are present. Secondary venation is semicraspedodromous. Intercostal tertiaries are alternate to opposite percurrent, simple or branched. Teeth are compound and crenate to serrate with some glandular apices.

Distribution at Falkland site	
Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP225?

Falkland Specimens:

RYS07-0887

Leaf Architecture - Dicots Only

LEAF

Laminar Size	mesophyll		Petiolar Attach.	not visible	
Clamp Size	mesophyll 2		Base Angle	not visible	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio: 1.2:1	Apex Shape	convex	
Base Symmetry	not visible		Margin Type	crenate, serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	simple	Minor 2° course	semicraspedodromous
# of Basal Veins	not visible	Inter-2° Veins	absent
2° Vein Category	semicraspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	uniform	Distal course	not applicable
2° attachment	deflected	Vein frequency	not applicable

3° to 5°

3° Vein Category	alternate percurrent	opposite percurrent	Epimedial3°	alternate percurrent
3° Vein Course	sinuous	convex	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially		4° Vein Category	alternate percurrent
Exterior tertiary course	looped		5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	2	Teeth Close	○ yes ◉ no
Teeth/cm	2	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	◉ yes ○ no
Shape	cv/cv st/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	running from sinus

Falkland (BC) Flora	Morphotype Name	Hamamelidaceae sp.	Morphotype #	FL141

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Hamamelidaceae	Genus		Type spec. #	RYS07-0893

PHOTO

Description of morphotype:

Notophyll elliptic leaf with minutely serrate, glandular teeth. Lamina is symmetrical and unlobed. Primary venation is is basal actinodromous with compound agrophic veins. Secondary venation is craspedodromous. Veins depart the midvein at an acute angle and travel in straight course to the margin. Intersecondary veins present. Intercostal tertiaries are opposite percurrent. Teeth are minutely serrate (serrulate), closely spaced, and glandular.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0893

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	Petiolar Attach.	marginal
Clamp Size	mesophyll 1	Base Angle	obtuse
		Apex Angle	acute
Laminar Shape	elliptic	Base Shape	cordate
Laminar Symmetry	symmetrical	Apex Shape	not visible
L:W Ratio	1.9:1	Margin Type	serrate
Base Symmetry	not visible	Lobation	unlobed

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	absent
Agrophic Veins	compound	Minor 2° course	craspedodromous
# of Basal Veins	5	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	reticulating or ramifying
2° attachment	excurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	mixed percurrent
3° Vein Course	convex	Epimedial3° proximal course	acute to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing basally	4° Vein Category	not visible
Exterior tertiary course	terminating at margin	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	12	Teeth Round	○ yes ◉ no
Spacing	regular	Teeth Acute	◉ yes ○ no
Shape	st/st fl/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Pinaceae sp.	Morphotype #	FL142
Major Plant Group	CON	Organ Type	Reproductive
Plant Family	Pinaceae	Genus	
Type spec. #	RYS06-0116		

PHOTO

Description of morphotype:

Pinaceous pollen cone. Cone is ~30 mm x 7 mm. Central axis ~1.2 mm wide with helically arranged sporophylls.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0116

Leaf Architecture - Dicots Only

LEAF

Laminar Size
Clamp Size
Laminar Shape
Laminar Symmetry
L:W Ratio
Base Symmetry
Petiolar Attach.
Base Angle
Apex Angle
Base Shape
Apex Shape
Margin Type
Lobation

1° to 2°

1° Vein Category
Agrophic Veins
# of Basal Veins
2° Vein Category
2° Vein Spacing
2° Vein Angle
2° attachment
Interior secondaries
Minor 2° course
Inter-2° Veins
Length
Proximal course
Distal course
Vein frequency

3° to 5°

3° Vein Category
3° Vein Course
3° Angle to 1°
3° Vein Angle Variability
Exterior tertiary course
Epimedial3°
Epimedial3° proximal course
Epimedial3° distal course
4° Vein Category
5° Vein Category

FINE VEINS

Areolation
F.E.V.s
Marginal Ultimate Venation

TEETH

# of Orders
Teeth/cm
Spacing
Shape
Sinus
Apex
Teeth Close ◌ yes ◌ no
Teeth round ◌ yes ◌ no
Teeth acute ◌ yes ◌ no
Principal vein
Termination
Accesory vein

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL143

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0723

PHOTO

Description of morphotype:

Notophyll elliptic leaf with irregular crenate teeth. Lamina is symmetrical and unlobed. Apex is obtuse and convex. Base angle is acute, shape is not visible but may be cuneate. Primary venation pinnate. Secondary venation craspedodromous, veins departing the midvein at an acute angle traveling in a fairly straight course to the margin where they terminate at the apices of glandular teeth. The angle of departure from the midvein becomes more acute near the base of the lamina. Intersecondary and agrophic veins absent. Intercostal tertiaries opposite percurrent. Teeth are simple, crenate, and irregularly spaced with glandular apices.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

RP217?
MB034?

Falkland Specimens:

RYS06-0723

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	Petiolar Attach.	not visible
Clamp Size	mesophyll 1	Base Angle	acute
Laminar Shape	elliptic	Apex Angle	obtuse
Laminar Symmetry	symmetrical	Base Shape	not visible
L:W Ratio	1.9:1	Apex Shape	convex
Base Symmetry	not visible	Margin Type	crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	uniform	Proximal course	not applicable
2° Vein Angle	smoothly decreasing towards base	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	straight; convex	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	alternate percurrent
Exterior tertiary course	terminating at margin	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

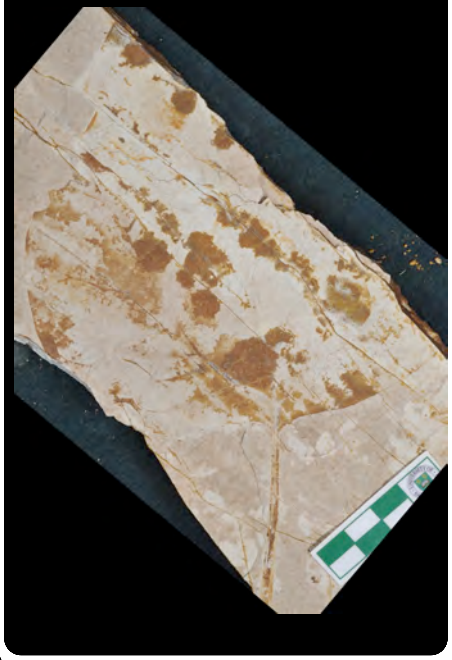
TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	4	Teeth round	◉ yes ○ no
Spacing	irregular	Teeth acute	○ yes ◉ no
Shape	cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL144

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0137

PHOTO



Description of morphotype:

Leaf is very poorly preserved, but is distinct in characteristic. Large mesophyll ovate leaf with entire margin. Petiole is stout and long (5+ cm). Base is obtuse and rounded. Apex is not preserved. Lamina is unlobed. Primary venation is suprabasal actinodromous venation with agrophic veins. Higher order venation indistinct. Margin is entire.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0137

Leaf Architecture - Dicots Only

LEAF

Laminar Size	mesophyll		Petiolar Attach.	marginal	
Clamp Size	mesophyll 3		Base Angle	obtuse	Apex Angle: not visible
Laminar Shape	ovate		Base Shape	convex	rounded
Laminar Symmetry	not visible	L:W Ratio: >1<2:1	Apex Shape	not visible	
Base Symmetry	symmetrical		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	suprabasal actinodromous	Interior secondaries	not visible
Agrophic Veins	simple	Minor 2° course	simple brochidodromous
# of Basal Veins	1	Inter-2° Veins	not visible
2° Vein Category	not visible	Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	cf. Crataegus sp.	Morphotype #	FL145
Major Plant Group	DIC	Organ Type	Leaf
Plant Family	Rosaceae	Genus	*Crataegus*
Type spec. #	RYS08-0023		

PHOTO

Description of morphotype:

Microphyll leaf, oblong to elliptic in shape with symmetrical lamina, and base symmetrical to basal insertion asymmetrical. Leaf is pinnately lobed (pinnatisect), and lobes are toothed (broadly serrate with glandular apices). Primary venation is pinnate. Major secondaries are craspedodromous and irregularly spaced. Intersecondary veins are present. Intercostal tertiary veins are irregular reticulate. Tooth spacing is irregular, and teeth are compound with two orders of teeth. Teeth occur about 3 per cm with angular sinus.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes (RP=Republic, MB=McAbee)

RP032
MB044?

Falkland Specimens:

RYS07-0874
RYS07-0936
RYS08-0023

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 2	Base Angle	obtuse
Laminar Shape	oblong; elliptic	Apex Angle	obtuse
Laminar Symmetry	symmetrical	Base Shape	decurrent; cuneate
L:W Ratio	2:1	Apex Shape	convex
Base Symmetry	basal insertion asymmetrical	Margin Type	serrate
		Lobation	pinnately

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	craspedodromous
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	craspedodromous	Length	<50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	smoothly increasing towards base	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	irregular reticulate	Epimedial3°	reticulate
3° Vein Course	not applicable	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable	Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable	4° Vein Category	irregular reticulate
Exterior tertiary course	looped	5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	moderately developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	looped

TEETH

# of Orders	2	Teeth Close	○ yes ◉ no
Teeth/cm	3	Teeth Round	○ yes ◉ no
Spacing	irregular	Teeth Acute	◉ yes ○ no
Shape	fl/cv; cc/cv; cv/cv	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora | Morphotype Name: Fern | Morphotype #: FL146

Major Plant Group: PTE | Organ Type: Leaf | Plant Family: | Genus: | Type spec. #: RYS07-0816

PHOTO

Description of morphotype:

Small fern pinna. Preserved portion is ~3 cm x 1.4 cm. Pinnules are toothed and oval in shape, more rounded than FL131, but venation is indistinct. Possibly Osmundaceae.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0816

Leaf Architecture - Dicots Only

LEAF

Laminar Size | Clamp Size | Laminar Shape | Laminar Symmetry | L:W Ratio | Base Symmetry

Petiolar Attach. | Base Angle | Apex Angle | Base Shape | Apex Shape | Margin Type | Lobation

1° to 2°

1° Vein Category | Agrophic Veins | # of Basal Veins | 2° Vein Category | 2° Vein Spacing | 2° Vein Angle | 2° attachment

Interior secondaries | Minor 2° course | Inter-2° Veins | Length | Proximal course | Distal course | Vein frequency

3° to 5°

3° Vein Category | 3° Vein Course | 3° Angle to 1° | 3° Vein Angle Variability | Exterior tertiary course

Epimedial3° | Epimedial3° proximal course | Epimedial3° distal course | 4° Vein Category | 5° Vein Category

FINE VEINS

Areolation | F.E.V.s | Marginal Ultimate Venation

TEETH

# of Orders | Teeth/cm | Spacing | Shape | Sinus | Apex

Teeth Close ◌ yes ◌ no | Teeth round ◌ yes ◌ no | Teeth acute ◌ yes ◌ no | Principal vein | Termination | Accesory vein

Falkland (BC) Flora

Morphotype Name	Deviacer sp.					Morphotype #	FL147
Major Plant Group	DIC	Organ Type	Fruit	Plant Family	Sapindaceae	Genus	*Deviacer*
Type spec. #	RYS07-0770						

PHOTO

Description of morphotype:

Fruit is a samara. Attachment scar is truncated but indicates that the strongly veined "back" of the wing was medial rather than marginal (the opposite of Acer). Seed body is ~ 7 mm long x 4 mm wide , with wing margin about 180 degrees (approximately in line with wing margin). Sulcus shallow and indistinct.

Distribution at Falkland site

- ☐ Unit 3
- ☐ Unit 2
- ☒ Unit 1
- ☐ Scree

Similar Morphotypes

RP=Republic
MB=McAbee

RP147

Falkland Specimens:

Specimens: RYS07-0770

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Incertae sedis	Morphotype #	FL148
Major Plant Group	DIC	Organ Type	Reproductive
Plant Family		Genus	
Type spec. #	RYS07-0203		

PHOTO

Description of morphotype:

Samara with large seed body relative to wing. Seed is rounded, 6 x 5 mm, wing is 9 mm x 3.5 mm. Possibly an Acer samara?

Distribution at Falkland site

- [x] Unit 3
- [ ] Unit 2
- [ ] Unit 1
- [ ] Scree

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0203

Leaf Architecture - Dicots Only

LEAF

Laminar Size | Clamp Size | Laminar Shape | Laminar Symmetry | L:W Ratio | Base Symmetry | Petiolar Attach. | Base Angle | Apex Angle | Base Shape | Apex Shape | Margin Type | Lobation

1° to 2°

1° Vein Category | Agrophic Veins | # of Basal Veins | 2° Vein Category | 2° Vein Spacing | 2° Vein Angle | 2° attachment | Interior secondaries | Minor 2° course | Inter-2° Veins | Length | Proximal course | Distal course | Vein frequency

3° to 5°

3° Vein Category | 3° Vein Course | 3° Angle to 1° | 3° Vein Angle Variability | Exterior tertiary course | Epimedial3° | Epimedial3° proximal course | Epimedial3° distal course | 4° Vein Category | 5° Vein Category

FINE VEINS

Areolation | F.E.V.s | Marginal Ultimate Venation

TEETH

# of Orders | Teeth/cm | Spacing | Shape | Sinus | Apex | Teeth Close ◌ yes ◌ no | Teeth round ◌ yes ◌ no | Teeth acute ◌ yes ◌ no | Principal vein | Termination | Accesory vein

Falkland (BC) Flora	Morphotype Name	Cupressinocladus interruptus	Morphotype #	FL149

Major Plant Group	CON	Organ Type	Leaf	Plant Family	Cupressaceae	Genus	*Cupressinocladu*	Type spec. #	RYS07-0834

PHOTO

Description of morphotype:

Axis bears decussately arranged scale-like leaves. Distinct from FL031 in having branchlets that are oppositely arranged, rather than alternate.

Distribution at Falkland site

Unit 3	☐
Unit 2	☐
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0673
RYS07-0834

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	
Laminar Shape			Apex Angle	
Laminar Symmetry		L:W Ratio	Base Shape	
Base Symmetry			Apex Shape	
			Margin Type	
			Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora

Morphotype Name	Glyptostrobus sp.					Morphotype #	FL150
Major Plant Group	CON	Organ Type	Axis	Plant Family	Cupressaceae	Genus	*Glyptostrobus*
Type spec. #	RYS07-0500						

PHOTO

Description of morphotype:

Axis bears closely appressed scale-like leaves which are arranged helically, rather than in decussate pairs as in FL031.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☒
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0511
RYS07-0500
RYS07-0809
RYS07-0870

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	
Laminar Shape		Apex Angle	
Laminar Symmetry		L:W Ratio	
Base Symmetry		Base Shape	
		Apex Shape	
		Margin Type	
		Lobation	

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL152

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0783

PHOTO

Description of morphotype:

Notophyll elliptic leaf with entire margin. Lamina is unlobed and symmetrical. Texture is chartaceous. Apex is acute and appears acuminate (concave) although tip is not completely preserved. Base is obtuse and convex. Primary venation is pinnate. Secondary venation is brochidodromous. Higher order venation indistinct. Margin is entire.

Distribution at Falkland site

Unit 3	☐
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0783

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	Base Angle	obtuse
Laminar Shape	elliptic	Apex Angle	acute
Laminar Symmetry	symmetrical	Base Shape	convex
L:W Ratio	2.5:1	Apex Shape	acuminate
Base Symmetry	symmetrical	Margin Type	entire
		Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	not visible	Minor 2° course	not visible
# of Basal Veins	1	Inter-2° Veins	not visible
2° Vein Category	brochidodromous	Length	
2° Vein Spacing	not visible	Proximal course	
2° Vein Angle	not visible	Distal course	
2° attachment	excurrent	Vein frequency	

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis		Morphotype #	FL153
Major Plant Group: DIC	Organ Type: Leaf	Plant Family	Genus	Type spec. #	RYS08-0051

PHOTO

Description of morphotype:

Microphyll to notophyll elliptic leaf with acuminate apex and serrate margin. Lamina is symmetrical and unlobed. Apex is acute with acuminate apex. Base is acute and convex in shape. Primary venation is pinnate. Secondary venation is craspedodromous. Intersecondary and agrophic veins absent. Intercostal tertiaries are opposite percurrent. Teeth are irregularly spaced, shallowly serrate, and glandular.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0519
RYS06-0971
RYS07-0122
RYS08-0051

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal	
Clamp Size	microphyll 3	mesophyll 1	Base Angle	acute	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	convex	
Laminar Symmetry	symmetrical	L:W Ratio: 2.6:1	Apex Shape	acuminate	
Base Symmetry	not visible		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	opposite percurrent
3° Vein Course	sinuous	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse	Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	decreasing exmedially	4° Vein Category	opposite percurrent
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	3	Teeth Round	○ yes ◉ no
Spacing	irregular	Teeth Acute	◉ yes ○ no
Shape	cv/st cv/fl	Principal vein	present
Sinus	angular	Termination	at apex of tooth
Apex	non-specific glandular	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL155

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family		Genus		Type spec. #	RYS06-1037

PHOTO

Description of morphotype:

Two pedicels, >5 mm long (incomplete) with developing fruits. May be in pairs but point of attachment not preserved. Each structure has numerous persistent styles. Possibly rosaceous.

Distribution at Falkland site

- Unit 3 ☒
- Unit 2 ☐
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-1037
RYS06-0072

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.		
Clamp Size			Base Angle		Apex Angle
Laminar Shape			Base Shape		
Laminar Symmetry		L:W Ratio	Apex Shape		
Base Symmetry			Margin Type		Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL156

Major Plant Group	CON	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS06-0959

PHOTO

Description of morphotype:

Conifer with broad, blunt tipped needles. Poorly preserved, but appears distinct from other conifer morphotypes. Needles about 15 mm long and 3.5 mm wide. Attachment appears decurrent.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☒
- Unit 1 ☐
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0959

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	○ yes ○ no
Teeth/cm		Teeth round	○ yes ○ no
Spacing		Teeth acute	○ yes ○ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL158

Major Plant Group	DIC	Organ Type	Reproductive	Plant Family		Genus		Type spec. #	RYS06-1042

PHOTO

Description of morphotype:

Small pedunculate infructescence. Peduncle is ~1.7 cm long, curved, and expanded at the base. Terminal cluster of four or five bracts or capsules, each one elliptic in shape with an acute apex, about 6 mm long.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-1042

Leaf Architecture - Dicots Only

LEAF				
Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°			
1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°			
3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS			
Areolation			
F.E.V.s			
Marginal Ultimate Venation			

TEETH			
# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Alnus sp. 3	Morphotype #	FL159

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Betulaceae	Genus	*Alnus*	Type spec. #	RYS07-0814

PHOTO

Description of morphotype:

Microphyll to notophyll leaf, elliptic to ovate in shape. Apex angle is acute and straight or convex in shape. Base angle is obtuse and convex or cuneate in shape. Pinnate primary venation with craspedodromous secondaries that follow a straight course to the margin. Agrophic veins and intersecondaries absent. Tertiary veins are opposite percurrent. Higher order venation indistinct. Teeth are compound and glandular, and larger and more rounded than in FL020. Compare with FL020 and FL117 (possibly the same).

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☒
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-0002, RYS06-0017, RYS06-0018, RYS06-0076, RYS06-0965, RYS06-0994, RYS07-0103, RYS07-0814

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	notophyll	Petiolar Attach.	marginal		
Clamp Size	microphyll 3	mesophyll 1	Base Angle	obtuse	Apex Angle	acute
Laminar Shape	elliptic	ovate	Base Shape	convex	cuneate	
Laminar Symmetry	symmetrical	L:W Ratio 1.7:1	Apex Shape	straight	convex	
Base Symmetry	not visible		Margin Type	serrate	Lobation	unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	absent
2° Vein Category	craspedodromous	Length	not applicable
2° Vein Spacing	decreasing toward base	Proximal course	not applicable
2° Vein Angle	smoothly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	opposite percurrent		Epimedial3°	opposite percurrent
3° Vein Course	convex	sinuous	Epimedial3° proximal course	perpendicular to midvein
3° Angle to 1°	obtuse		Epimedial3° distal course	parallel to intercostal tertiaries
3° Vein Angle Variability	increasing exmedially		4° Vein Category	not visible
Exterior tertiary course	terminating at margin		5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	2				Teeth Close	○ yes ◉ no
Teeth/cm	3-4				Teeth Round	○ yes ◉ no
Spacing	regular				Teeth Acute	◉ yes ○ no
Shape	cv/cv	st/st	fl/fl	cc/fl	Principal vein	present
Sinus	angular				Termination	at apex of tooth
Apex	non-specific glandular				Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL160

Major Plant Group	DIC	Organ Type	Leaf	Plant Family		Genus		Type spec. #	RYS07-0871

PHOTO

Description of morphotype:

Notophyll ovate leaf with simple teeth with long basal flanks. Lamina is symmetrical and unlobed. Apex is acute and convex to slightly acuminate. Base is not preserved. Primary venation is pinnate. Secondary veins are craspedodromous to semicraspedodromous. Major secondary veins sometimes terminate at apex of tooth. sometimes at a sinus, and sometimes branch before reaching the margin. Intersecondary veins are present. Intercostal tertiaries are opposite percurrent. Higher order venation indistinct. Teeth are simple and serrate, with long basal flanks. Teeth are regularly spaced with simple apices.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☒
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS06-1015
RYS07-0871

Leaf Architecture - Dicots Only

LEAF

Laminar Size	notophyll		Petiolar Attach.	not visible	
Clamp Size	mesophyll 1		Base Angle	not visible	Apex Angle: acute
Laminar Shape	ovate	elliptic	Base Shape	not visible	
Laminar Symmetry	symmetrical	L:W Ratio: >2:1	Apex Shape	convex	acuminate
Base Symmetry	not visible		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	not visible	Minor 2° course	not applicable
# of Basal Veins	not visible	Inter-2° Veins	present
2° Vein Category	craspedodromous to semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	irregular	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	parallel to major secondary
2° attachment	excurrent	Vein frequency	~1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	Epimedial3°	not visible
3° Vein Course	sinuous	Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse	Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

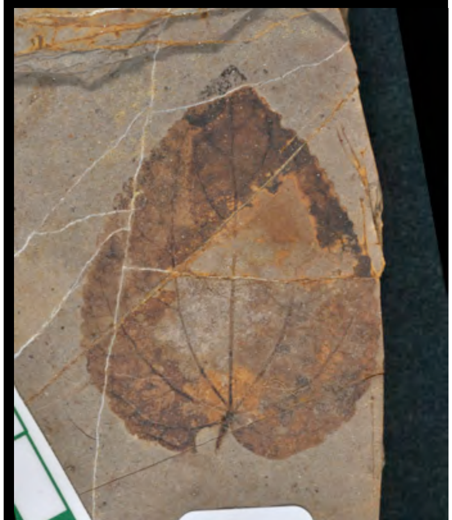
TEETH

# of Orders	1	Teeth Close	○ yes ◉ no
Teeth/cm	1	Teeth Round	○ yes ◉ no
Spacing	regular	Teeth Acute	◉ yes ○ no
Shape	cv/cc cv/fl st/st st/fl	Principal vein	present
Sinus	angular	Termination	sinus or apex
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Tetracentron sp.	Morphotype #	FL161

Major Plant Group	Organ Type	Plant Family	Genus	Type spec. #
DIC	Leaf	Trochodendraceae	*Tetracentron*	RYS07-0962

PHOTO



Description of morphotype:

Ovate leaf with cordate base and crenate margin with simple teeth. Laminar size microphyll. Primary venation is basal actinodromous with 7 basal veins and compound agrophic veins. Major secondaries are festooned semicraspedodromous with decurrent attachment. Minor secondary course semicraspedodromous. Higher order venation not clearly visible. Tooth spacing regular, teeth simple and rounded (cv/cv) and ~4/cm. Tetracentron sp. from Republic is described as having glandular teeth. Glandular tooth apices in this specimen are not apparent, but may be due to preservation.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

RP210

Falkland Specimens:

RYS07-0962

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll	Petiolar Attach.	marginal
Clamp Size	microphyll 3	Base Angle	obtuse
Laminar Shape	ovate	Apex Angle	acute
Laminar Symmetry	symmetrical	Base Shape	cordate
L:W Ratio	1.3:1	Apex Shape	convex
Base Symmetry	symmetrical	Margin Type	crenate
		Lobation	unlobed

1° to 2°

1° Vein Category	basal actinodromous	Interior secondaries	absent
Agrophic Veins	compound	Minor 2° course	semicraspedodromous
# of Basal Veins	7	Inter-2° Veins	absent
2° Vein Category	festooned semicraspedodromous	Length	not applicable
2° Vein Spacing	increasing toward base	Proximal course	not applicable
2° Vein Angle	abruptly increasing towards base	Distal course	not applicable
2° attachment	decurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	not visible	Epimedial3°	not visible
3° Vein Course	not visible	Epimedial3° proximal course	not visible
3° Angle to 1°	not visible	Epimedial3° distal course	not visible
3° Vein Angle Variability	not visible	4° Vein Category	not visible
Exterior tertiary course	not visible	5° Vein Category	not visible

FINE VEINS

Areolation	not visible
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders	1	Teeth Close	◉ yes ○ no
Teeth/cm	4	Teeth round	◉ yes ○ no
Spacing	regular	Teeth acute	○ yes ◉ no
Shape	cv/cv	Principal vein	
Sinus	angular	Termination	not visible
Apex	simple	Accesory vein	not visible

Falkland (BC) Flora	Morphotype Name	Incertae sedis	Morphotype #	FL162
Major Plant Group: DIC	Organ Type: Reproductive	Plant Family:	Genus:	Type spec. #: RYS06-1044

PHOTO

Description of morphotype:

Infructescence with fruits in pairs. Each fruit appears to be a valved capsule, ~10 mm long x 8 mm wide, dehiscent. Fruits borne terminally in pairs. Possibly Fagus langevinii cupules.

Distribution at Falkland site	
Unit 3	☒
Unit 2	☐
Unit 1	☐
Scree	☐

Similar Morphotypes

RP=Republic
MB=McAbee

MB318?
RP010?

Falkland Specimens:

RYS06-1044

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora		Morphotype Name	?Prunus sp.				Morphotype #	FL163	
Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Rosaceae	Genus	*?Prunus*	Type spec. #	RYS07-0932

PHOTO

Description of morphotype:

Microphyll leaf with small, shallow, serrate teeth. Laminar tissue extends along the petiole (basal insertion point is asymmetrical) and base shape is concave to decurrent . Secondary venation is semicraspedodromous and intersecondary veins are present. Teeth are very small and close together, 7-15 teeth per cm, some with glandular and some with simple apices. Glandular teeth more obvious in specimen RYS07-0217.

Distribution at Falkland site		Similar Morphotypes	
	Unit 3 ☒	RP=Republic MB=McAbee	RP054 MB045?
	Unit 2 ☐		
	Unit 1 ☐		
	Scree ☒		

Falkland Specimens:

RYS07-0217
RYS07-0932

Leaf Architecture - Dicots Only

LEAF

Laminar Size	microphyll		Petiolar Attach.	marginal	
Clamp Size	microphyll 2		Base Angle	acute	Apex Angle: acute
Laminar Shape	elliptic		Base Shape	decurrent	concave
Laminar Symmetry	symmetrical	L:W Ratio: 3.3:1	Apex Shape	straight	
Base Symmetry	basal insertion asymmetrical		Margin Type	serrate	Lobation: unlobed

1° to 2°

1° Vein Category	pinnate	Interior secondaries	absent
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	1	Inter-2° Veins	present
2° Vein Category	semicraspedodromous	Length	>50% of subjacent secondary
2° Vein Spacing	increasing toward base	Proximal course	parallel to major secondaries
2° Vein Angle	uniform	Distal course	perpendicular to subjacent secondary
2° attachment	decurrent	Vein frequency	<1 per intercostal area

3° to 5°

3° Vein Category	opposite percurrent	irregular reticulate	Epimedial3°	not visible
3° Vein Course	sinuous		Epimedial3° proximal course	not visible
3° Angle to 1°	obtuse		Epimedial3° distal course	not visible
3° Vein Angle Variability	increasing basally		4° Vein Category	irregular reticulate
Exterior tertiary course	terminating at margin		5° Vein Category	dichotomizing (fevs)

FINE VEINS

Areolation	poorly developed
F.E.V.s	2 or more branched
Marginal Ultimate Venation	incomplete loops

TEETH

# of Orders	1		Teeth Close	yes no
Teeth/cm	7-15		Teeth round	yes no
Spacing	regular		Teeth acute	yes no
Shape	st/cv	cc/cv	Principal vein	present
Sinus	angular		Termination	marginal
Apex	simple or glandular		Accesory vein	not visible

Falkland (BC) Flora

Morphotype Name	Azolla sp.			Morphotype #	FL164
Major Plant Group	PTE	Organ Type	Axis	Plant Family	Azollaceae
Genus	*Azolla*	Type spec. #	RYS07-0963		

PHOTO

Description of morphotype:

Axis of small floating fern Azolla, with numerous small, overlapping round to scale-like leaves. Leaves ~1 mm in diameter.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS07-0963

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FV IE NI EN RS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	Nelumbo sp.	Morphotype #	FL165

Major Plant Group	DIC	Organ Type	Leaf	Plant Family	Nelumbonaceae	Genus	*Nelumbo*	Type spec. #	RYS07-0965

PHOTO

Description of morphotype:

Large peltate leaf. Diameter >15 cm. Leaf has ~9 primary veins radiating from a central point and veins bifurcate before reaching the margin, with branches joining other primary branches and/or secondary veins to form loops. Secondary venation poorly developed. Tertiary veins irregular reticulate to opposite percurrent, forming a coarse net across the leaf surface, with a finer but still irregular reticulum formed by quaternary veins. Margin is poorly preserved but is likely entire. Note that this taxon is not used for leaf physiognomy techniques for estimating paleoclimate (CLAMP and leaf margin analysis) as it is not a woody dicot.

Distribution at Falkland site

Unit 3	☐
Unit 2	☐
Unit 1	☐
Scree	☒

Similar Morphotypes

RP=Republic
MB=McAbee

MB087

Falkland Specimens:

RYS07-0965

Leaf Architecture - Dicots Only

LEAF

Laminar Size	macrophyll		Petiolar Attach.	peltate-central	
Clamp Size	mesophyll 3		Base Angle	circular	Apex Angle: obtuse
Laminar Shape	elliptic	orbicular	Base Shape	rounded	
Laminar Symmetry	symmetrical	L:W Ratio	Apex Shape	rounded	
Base Symmetry	not applicable		Margin Type	entire	Lobation: unlobed

1° to 2°

1° Vein Category	actinodromous	Interior secondaries	present
Agrophic Veins	none	Minor 2° course	not applicable
# of Basal Veins	9	Inter-2° Veins	absent
2° Vein Category	festooned brochidodromous	Length	not applicable
2° Vein Spacing	irregular	Proximal course	not applicable
2° Vein Angle	irregular	Distal course	not applicable
2° attachment	excurrent	Vein frequency	not applicable

3° to 5°

3° Vein Category	irregular reticulate	opposite percurrent	Epimedial3°	not applicable
3° Vein Course	straight	convex	Epimedial3° proximal course	not applicable
3° Angle to 1°	not applicable		Epimedial3° distal course	not applicable
3° Vein Angle Variability	not applicable		4° Vein Category	alternate percurrent
Exterior tertiary course	looped		5° Vein Category	not visible

FIVE NERINS

Areolation	moderately developed
F.E.V.s	not visible
Marginal Ultimate Venation	not visible

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth Round	◌ yes ◌ no
Spacing		Teeth Acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	cf. Prunus sp.		Morphotype #	FL166
Major Plant Group: DIC	Organ Type: Reproductive	Plant Family: Rosaceae	Genus: *cf. Prunus*	Type spec. #	RYS08-0048

PHOTO

Description of morphotype:

Solitary flower on pedicel. Pedicel 6 mm long. Numerous stamens and hypanthium are visible. There is a solitary carpel with elongated style and broad stigmatic region.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☐
- Scree ☒

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS08-0048

Leaf Architecture - Dicots Only

LEAF

Laminar Size			Petiolar Attach.	
Clamp Size			Base Angle	Apex Angle
Laminar Shape			Base Shape	
Laminar Symmetry		L:W Ratio	Apex Shape	
Base Symmetry			Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINE VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

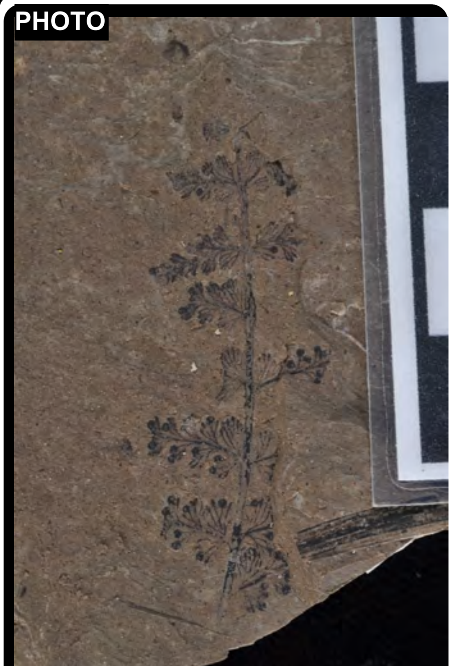
TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

Falkland (BC) Flora	Morphotype Name	?Adiantum sp. 2	Morphotype #	FL167

Major Plant Group	PTE	Organ Type	Leaf	Plant Family	Pteridaceae	Genus	*?Adiantum*	Type spec. #	RYS08-0064

PHOTO



Description of morphotype:

Fertile fern frond. Portion portion is 4.5+ cm long. Venation pattern is dichotomizing, but pinnules appear more dissected than in FL131. Round sori are visible on leaf margins. This may be the fertile form of FL131.

Distribution at Falkland site

- Unit 3 ☐
- Unit 2 ☐
- Unit 1 ☒
- Scree ☐

Similar Morphotypes

RP=Republic
MB=McAbee

Falkland Specimens:

RYS08-0064

Leaf Architecture - Dicots Only

LEAF

Laminar Size		Petiolar Attach.	
Clamp Size		Base Angle	Apex Angle
Laminar Shape		Base Shape	
Laminar Symmetry	L:W Ratio	Apex Shape	
Base Symmetry		Margin Type	Lobation

1° to 2°

1° Vein Category		Interior secondaries	
Agrophic Veins		Minor 2° course	
# of Basal Veins		Inter-2° Veins	
2° Vein Category		Length	
2° Vein Spacing		Proximal course	
2° Vein Angle		Distal course	
2° attachment		Vein frequency	

3° to 5°

3° Vein Category		Epimedial3°	
3° Vein Course		Epimedial3° proximal course	
3° Angle to 1°		Epimedial3° distal course	
3° Vein Angle Variability		4° Vein Category	
Exterior tertiary course		5° Vein Category	

FINER VEINS

Areolation	
F.E.V.s	
Marginal Ultimate Venation	

TEETH

# of Orders		Teeth Close	◌ yes ◌ no
Teeth/cm		Teeth round	◌ yes ◌ no
Spacing		Teeth acute	◌ yes ◌ no
Shape		Principal vein	
Sinus		Termination	
Apex		Accesory vein	

APPENDIX B:

SUPPLEMENTAL DATA FOR CHAPTER FIVE

This appendix provides information to supplement Chapter 5, "Paleoclimate reconstruction of the early Eocene Falkland locality, Okanagan Highlands, Canada – a comparison of physiognomic and floristic approaches." Table B1 provides the data underlying the calculation of mean annual precipitation for the Falkland site using leaf area analysis (Wilf et al., 1998). Table B2 contains the CLAMP scores for the Falkland site as a whole, and the three individual units. Woody dicot taxa were scored for 31 leaf traits as described by Wolfe (1993) and later updates to the CLAMP methodology (CLAMP, 2010). Table B3 contains a list of the fossil taxa and nearest living relatives used in the application of the coexistence approach (Mosbrugger and Utescher, 1997), along the climate data for the modern taxa derived from the following sources: PALAEOFLORA (2010), Thompson et al. (1999), Natural Resources Canada (2007), and Integrated Botanical Information System (2010) of the Australian National Herbarium.

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PALAEOFLORA, 2010, Data base for palaeoclimate reconstructions using the coexistence approach: http://www.palaeoflora.de/ (October, 2010).

Thompson, R.S., Anderson, K.H., and Bartlein, P.J., 1999, Atlas of Relations between Climatic Parameters and Distributions of Important Trees and Shrubs in North America: U.S. Geological Survey Professional Paper 1650A, 269 p., and 1650B, 423 p.

Wilf, P., Wing, S.L., Greenwood, D., and Greenwood, C. 1998, Using fossil leaves as paleoprecipitation indicators: an Eocene example: Geology, v. 26, p. 203–206.

Wolfe, J. A., 1993, A method of obtaining climatic parameters from leaf assemblages: United States Geological Survey Bulletin 2040, 71 p.

TABLE B1. LEAF SIZE DATA FOR THE FALKLAND FLORA

Morphotype	Mesophyll	Notophyll	Microphyll	Nanophyll	Whole Site	Unit 1	Unit 2	Unit 3
	Leaf size categories							
FL001			1		1			1
FL002			1		1			1
FL003	0.33	0.33	0.33		1	1	1	1
FL007			1		1			
FL008	0.33	0.33	0.33		1	1		
FL009			1		1			1
FL010			1		1			1
FL011	0.33	0.33	0.33		1		1	1
FL013	0.5	0.5			1		1	1
FL014		0.5	0.5		1		1	1
FL015	0.5		0.5		1		1	
FL016		1			1			1
FL018			1		1			1
FL020		0.5	0.5		1	1	1	1
FL021	0.25	0.25	0.25	0.25	1	1	1	1
FL022		0.5	0.5		1		1	1
FL023			0.5	0.5	1	1	1	1
FL024	0.33	0.33	0.33		1	1		1
FL025		1			1	1		
FL026	0.33	0.33	0.33		1	1		1
FL028		1			1			1
FL029		1			1	1	1	1
FL030		0.5	0.5		1	1	1	1
FL034		0.5	0.5		1	1	1	1
FL035			1		1		1	
FL039		0.5	0.5		1	1	1	1
FL040			0.5	0.5	1		1	1
FL044		0.5	0.5		1		1	1
FL047	1				1	1		
FL049		1			1			1
FL050		1			1			1
FL054			1		1		1	1
FL056		1			1			1
FL057		0.5	0.5		1		1	1
FL067		1			1	1	1	1
FL069	0.5	0.5			1	1		1
FL077			1		1		1	1
FL079		1			1			1
FL080			1		1	1		
FL082			1		1		1	1
FL084			1		1			1
FL086		1			1		1	
FL088		0.33	0.33	0.33	1	1	1	1
FL093			1		1	1		
FL097	1				1		1	
FL100		0.5	0.5		1	1	1	1
FL102			1		1			
FL110		0.5	0.5		1		1	1
FL111			1		1			
FL114		0.5	0.5		1	1	1	1
FL115	0.33	0.33	0.33		1	1	1	1
FL116			1		1			1
FL117		0.5	0.5		1		1	
FL118			1		1	1		1

Morphotype	Mesophyll	Notophyll	Microphyll	Nanophyll	Whole Site	Unit 1	Unit 2	Unit 3
	Leaf size categories							
FL122		1			1		1	
FL126		1			1		1	
FL127			1		1			1
FL128			1		1			
FL132		0.5	0.5		1			
FL134			1		1		1	
FL140	1				1		1	
FL141		1			1		1	
FL143		1			1			1
FL144	1				1			1
FL145			1		1			1
FL152		1			1		1	
FL153		0.5	0.5		1	1	1	1
FL159		0.5	0.5		1	1	1	1
FL160		1			1		1	1
FL161			1		1			
FL163			1		1			1
Totals (proportions)	Meso	Noto	Micro	Nano	71	24	38	49
Whole site	7.58	26.92	34.92	1.58				
	(0.11)	(0.38)	(0.49)	(0.02)				
Unit 1	3.25	9.58	10.08	1.08				
	(0.14)	(0.40)	(0.42)	(0.05)				
Unit 2	4.25	17.08	15.08	1.58				
	(0.11)	(0.45)	(0.40)	(0.04)				
Unit 3	3.75	19.58	24.08	1.58				
	(0.08)	(0.40)	(0.49)	(0.03)				
Size categories	Meso	Noto	Micro	Nano				
Mean of natural log areas*	9.11	8.01	6.51	4.32				
				MlnA†	7.31	7.36	7.38	7.24
				ln(MAP)§	4.77	4.80	4.81	4.73
				MAP (cm/yr)#	**118**	**122**	**123**	**114**
				SE Plus **	**51**	**53**	**53**	**49**
				SE Minus**	**36**	**37**	**37**	**34**

Notes: see Appendix A for a full description of morphotypes.
*Mean of natural log areas for each of the standard leaf size categories from Wilf et al. (1998)
†Sum of the proportions x the mean of the natural log area for each size category.
§Calculated by ln(MAP)=0.548MlnA+0.768 as per Wilf et al. (1998)
#Natural logarithm base *e* raised to the power of ln(MAP).
**Standard error of 0.359 added to or subtracted from ln(MAP).

TABLE B2. CLAMP SCORES FOR THE FALKLAND FLORA

	Lamina dissection	Margin characters						Leaf size								
	Lobed	No Teeth	Teeth Regular	Teeth Close	Teeth Round	Teeth Acute	Teeth Compound	Nano	Lepto I	Lepto II	Micro I	Micro II	Micro III	Meso I	Meso II	Meso III
Whole site	11	20	44	29	29	51	25	0	1	1	2	22	32	32	8	2
Unit 1	6	25	38	29	21	54	29	0	0	0	5	12	35	33	14	1
Unit 2	9	16	45	27	28	55	27	0	0	0	4	13	35	37	10	1
Unit 3	11	10	52	31	31	59	28	0	1	1	3	24	27	35	6	3

	Apex characters				Base characters			L:W ratios					Leaf shape		
	Apex Emarg.	Apex Round	Apex Acute	Apex Attenuate	Base Cordate	Base Round	Base Acute	L:W <1:1	L:W 1-2:1	L:W 2-3:1	L:W 3-4:1	L:W >4:1	Obovate	Elliptic	Ovate
Whole site	6	53	28	13	21	46	32	4	57	30	7	1	12	61	27
Unit 1	0	43	38	19	20	52	27	4	65	26	4	0	13	54	33
Unit 2	8	50	23	19	24	54	22	8	59	30	3	0	7	63	30
Unit 3	4	48	33	15	17	49	35	2	53	36	6	2	10	62	28

Note: All scores are percentages.

TABLE B3. FALKLAND NEAREST LIVING RELATIVES AND MODERN CLIMATE DATA FOR COEXISTENCE APPROACH

Fossil Taxon	NLR	MAT min	MAT max	CMMT min	CMMT max	WMMT min	WMMT max	MAP min	MAP max	Source*	Notes
Relictual, monotypic and bitypic taxa											
Pseudolarix sp.	*Pseudolarix amabilis*	15.7	21.8	2.2	14.8	28.0	29.3	98	153	1	Monotypic
Cunninghamia sp.	*Cunninghamia lanceolata*	14.0	23.1	-0.5	17.0	27.8	29.3	58	181	1	Bitypic
Sequoia affinis	*Sequoia sempervirens*	9.4	18.4	4.7	9.6	13.5	21.9	41	195	1, 2, 3	Monotypic relictual
Nelumbo sp.	*Nelumbo nucifera*	2.5	27.2	-17.7	26.4	20.2	28.4	52	241	1	Bitypic
Cercidiphyllum sp.	*Cercidiphyllum japonicum*	7.6	17.0	-5.5	6.2	21.7	27.9	58	256	1	Monotypic
Comptonia columbiana	*Comptonia peregrina*	1.4	15.6	-12.9	4.4	17.2	26.8	71	208	1, 3	Monotypic
Dipteronia/*Bohlenia* sp.	*Dipteronia sinensis*	14.0	18.6	-0.5	8.1	26.5	28.9	58	119	1	Bitypic
Taxa used in coexistence approach											
Equisetum sp.	*Equisetum* sp.	-5.8	17.5	-23.7	8.1	5.9	26.6	29	344	3	Includes data on 9 N. American spp.
Azolla sp.	*Azolla* sp.	8.4	25.3	-2.0	22.1	15.0	27.9	45	123	1, 4	
Abies milleri	*Abies* sp.	-7.5	27.4	-30.0	25.6	7.1	29.5	11	449	1, 2, 3	Genus level data from Palaeoflora plus range of 8 N. American spp.
Picea sp.	*Picea* sp.	-12.4	21.7	-34.2	15.6	7.1	31.6	19	437	1, 2, 3	Genus level data from Palaeoflora plus range of 7 N. American spp.
Pinus sp.	*Pinus* sp.	-8.0	30.9	-30.4	26.0	7.1	31.6	6	441	2, 3	Includes data on 50 N. American spp.
Chamaecyparis sp.	*Chamaecyparis* sp.	-2.0	21.5	-10.9	13.2	7.8	28.9	33	437	1, 2, 3	Genus level data from Palaeoflora plus range of 3 N. American spp.
Cupressaceae sp.	*Thuja* sp.	-4.6	15.6	-24.2	10.4	7.9	26.8	24	437	1, 2, 3	Genus level data from Palaeoflora plus range of 2 N. American spp.
Taxodium dubium	*Taxodium* sp.	6.7	26.6	-1.4	24.0	14.1	31.4	22	262	1, 2, 3	
Sassafras hesperia	*Sassafras* sp.	5.6	22.0	-8.7	15.5	17.9	29.1	72	214	1, 2, 3	Genus level data from Palaeoflora plus data on *S. albidum*
Macginitea sp.	*Platanus* sp.	3.2	27.4	-10.9	25.6	13.7	31.0	34	254	1, 2, 3	Genus level data from Palaeoflora plus data on *P. occidentalis*
Ribes sp.	*Ribes* sp.	-4.9	16.3	-22.6	10.9	2.6	26.5	25	449	3	Includes data on 16 N. American spp.
Photinia pagae	*Photinia* sp.	6.9	27.0	-7.3	24.8	18.3	29.4	38	160	1	
Prunus sp.	*Prunus* sp.	-7.2	25.7	-27.5	23.9	12.0	28.6	22	315	1, 3	Genus level data from Palaeoflora plus range of 8 N. American spp.
cf. *Crataegus* sp.	*Crataegus* sp.	-1.8	21.4	-12.8	13.9	17.3	28.9	23	162	1, 3	Genus level data from Palaeoflora plus range of 10 N. American spp.
Ulmus okanaganensis	*Ulmus* sp.	-2.3	24.3	-25.8	19.2	13.5	31.9	20	429	1, 2, 3	Genus level data from Palaeoflora plus range of 7 N. American spp.
Fagus langevinii	*Fagus* sp.	0.7	23.1	-14.7	17.0	14.3	28.5	42	210	1, 2, 3	Genus level data from Palaeoflora plus *F. grandifolia*

Fossil Taxon	NLR	MAT min	MAT max	CMMT min	CMMT max	WMMT min	WMMT max	MAP min	MAP max	Source*	Notes
Quercus sp.	*Quercus* section Lobatae	3.4	21.1	-12.9	12.6	18.8	28.9	70	138	1	
Alnus parvifolia	*Alnus* sp.	-13.3	27.4	-40.9	25.6	7.1	38.6	4	469	1, 2	Genus level data from Palaeoflora plus range of 10 N. American spp.
Betula leopoldae	*Betula* sp.	-13.4	25.8	-34.8	21.1	3.9	30.8	9	437	1, 2	Genus level data from Palaeoflora plus range of 11 N. American spp.
?*Corylus* sp.	*Corylus* sp.	-4.9	24.0	-32.4	16.7	8.0	29.4	31	382	1, 2, 3	Genus level data from Palaeoflora plus range of 2 N. American spp.
Rhus malloryi	*Rhus* sp.	-2.3	24.9	-23.1	22.2	10.5	31.2	16	202	1, 2, 3	Genus level data from Palaeoflora plus range of 7 N. American spp.
Acer sp.	*Acer* sp.	-3.9	26.1	-24.6	22.2	7.1	29.8	8	437	1, 2, 3	Genus level data from Palaeoflora plus range of 13 N. American spp.
Aesculus sp.	*Aesculus* sp.	1.6	26.6	-12.2	25.0	10.8	29.5	27	545	1, 2, 3	Genus level data from Palaeoflora plus range of 3 N. American spp.
Koelreuteria arnoldi	*Koelreuteria* sp.	10.0	21.7	-7.3	15.2	20.2	28.4	40	210	1	
Ternstroemites sp. B	*Ternstroemia* sp.	9.1	26.6	-2.7	26.1	19.5	29.8	23	329	1	
	Range	10.0	15.6	-1.4	8.1	20.2	26.5	72	123		
	Midpoint	12.8		3.4		23.4		97			
	Error	2.8		4.8		3.2		26			

Notes: MAT = mean annual temperature; CMMT = cold month mean temperature; WMMT = warm month mean temperature; MAP = mean annual precipitation; NLR = nearest living relative. Temperature estimates are in °C; precipitation estimates are in cm/year.

*Data from available sources was merged to create the widest possible intervals. Sources are as follows: 1. PALAEOFLORA (2010) and data provided by T. Utesher (pers. comm. 2010) from Palaeoflora database; 2. Thompson et al. (1999); 3. Natural Resources Canada (2007); 4. Integrated Botanical Information System (2010), Australian National Herbarium.